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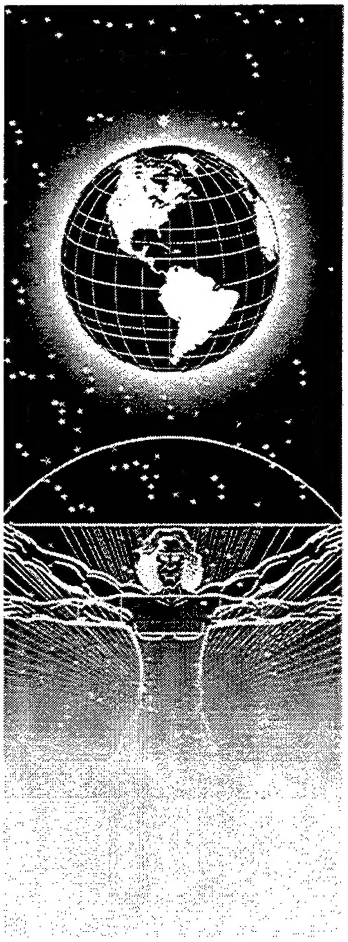

UNITED STATES AIR FORCE RESEARCH LABORATORY

The Effects of Aircraft Noise and Sonic Booms on Domestic Animals - A Preliminary Model and a Synthesis of the Literature and Claims

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FOR THE COMMANDER

Hendrick W Ruck

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In brief, our review of the claims files, which include 209 claims pertinent to aircraft noise, suggested that the major source of loss was panics induced in naive animals, and secondarily losses due to reproductive failure and failure to gain weight properly. These claims spanned a 32 year period and were remarkably uncommon when one considers the number of flight-miles logged over remote areas. Those deemed legitimate by Air Force examiners cost the USAF less than \$24, 000 per year countrywide, and over 62% of this cost could be attributed to a single claim for animal that escaped after stampeding away from aircraft. Thus, the economic loss to the community is small; the concerns about damage effects are political in nature.

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FOREWORD

This study was prepared by personnel from the Sea World Research Institute, Hubbs Marine Research Center. The Hubbs Marine Research Center is a member of the BBN Systems and Technologies Corporation (BBN) team of experts engaged in research on Noise and Sonic Boom Impact Technology (NSBIT).

The NSBIT program is conducted by the United States Air Force, Air Force Systems Command, Human Systems Division, and is under the direction of Captain Robert Kull, Jr., Program Manager. The BBN effort is conducted under Contract No. F33615-86-C-0530 and is under the direction of Mr. B. Andrew Kugler, BBN Program Manager. The work reported herein is in fulfillment of Subtask 20.7 of Task Order 0020.

EXECUTIVE SUMMARY

The effects of noise on domestic animals have been studied since the late 1950s, and have been reviewed repeatedly (e.g. Bell, 1972; Cottereau, 1978; Bond, 1970; Dufour, 1980). Based on these documents, the environmental planner would expect little hazard from conducting even very low-altitude flights over agricultural areas. However, based on the claims levied against the U.S. Air Force (USAF) for damages to domestic animals, the effects can be great, ranging from panicking animals to inducing catastrophic declines in reproductive capacity. We have reviewed both sources of data to resolve as much as possible the contradictions. Based on the synthesis of both sources, we have also created a "straw man" model of the effects of aircraft noise on domestic livestock and poultry.

In brief, our review of the claims files, which include 209 claims pertinent to aircraft noise, suggested that the major source of loss was panics induced in naive animals, and secondarily losses due to reproductive failure and failure to gain weight properly. These claims spanned a 32 year period and were remarkably uncommon when one considers the number of flight-miles logged over remote areas. Those deemed legitimate by Air Force examiners cost the USAF less than $24,000 per year countrywide, and over 62% of this cost could be attributed to a single claim for animals that escaped after stampeding away from aircraft. Thus, the economic loss to the community is small; the concerns about damage effects are political in nature.

The documentation for losses due to panic was often adequate and such claims were usually paid. This is understandable, as such effects are relatively easy to document. Reproductive losses (abortions, declines in egg production, etc.) were not evaluated adequately, nor were complaints that mother mink or sows consumed their own young. Damages such as weight loss, failure to thrive or loss of fertility were inadequately documented as well. Other explanations for these failures could always be given. Based on the documentation in the claims files, these effects must be considered

undocumented, as alternate explanations for the failures were not eliminated (e.g. organochloride poisoning of mink kits).

The studies suggested that serious consequences of noise are likely to be subtle and that effects due to cumulative exposure (e.g. reproductive effects, effects on weight) are likely to be undetectable at the typical exposures expected from aircraft overflights. For example, studies frequently discovered small effects on reproduction and growth when noise exposure was of high level and continuous. However, studies of aircraft noise per se, including those on low-altitude overflights and sonic booms, suggested that aircraft exposures are not adequate to produce reproductive effects, even in worst-case situations (exposure to 1/2 hour of continuous overflights at 30 meters, exposures of over 100 overflights in a two month period). These studies are by no means comprehensive, but they do not suggest catastrophic effects of the sort found in the claims files. As a result, we suspect that alternate explanations for catastrophic losses are more likely. To date, the experimental literature is inadequate to document long-term or subtle effects.

One caveat should be noted. Large effects might be noted in cases where animals were previously-stressed, such as by genetic predispositions, long periods of adverse weather conditions, or poor management practices. In these cases, it is very difficult to separate what effect may be attributed to the pre-stressor and what may be attributed to aircraft activity per se. Such pre-stressed animals represent a small proportion of the commercially-grown species and are thus only a small concern to the environmental planner. We developed a table, in coordination with experts on animal stress and animal husbandry, that lists the most important types of "pre-stressed" animals and the most likely effects on them of panic responses.

"Pre-stressing" conditions and subtle effects are best studied epidemiologically and clinically, at least until better hypotheses about the physiological effects of occasional frights can be generated. To date, this approach has not been used extensively to measure effects of aircraft activity. In the

future, it should be used to measure potential for weight loss, reduced fecundity, and abnormal terminations of pregnancy (e.g. resorbed embryos, abortions, stillbirths).

Modeling even the documented effects was difficult, as the literature and the claims files represent only a sketchy outline of even the best documented source of losses, panic-induced trauma. This is why the model is a "straw-man"; its predictions will be good enough to generate hypotheses and to estimate losses, but they will not be very accurate. At this point, only models of the possibility for traumatic damage are planned, although the machinery will be available to create models of production losses when they are better-understood.

No controlled study documented any serious accident or mortality in livestock, despite extreme exposures, and almost negligible losses in poultry (1 poult/2400 when the expected loss due to other causes is around 10-20%). Our model for traumatic loss is based on documentation of animal behavior and the potential for panic losses from the studies, and on the well-documented claims. The difference between the damages documented in the claims and the absence of losses in experimental literature is easily explained: differences in housing conditions (barbed wire as opposed to rail fences, and so on) can make some farm animals more susceptible, and the sheer numbers of animals exposed on a country-wide basis cannot be found in any experimental study. Based on the experiments and the claims, losses of large stock are on the order of a few tenths of a percent per animal-incident when animals are naive (incidents are very low-altitude overflights that induce panic running or aggression). The prospect for effect is modified by type and breed of animal and management practices.

Our "straw-man" model suggests how such effects might be forecasted. In brief, the logic of the model is as follows:

Naive animals respond most strongly, and will experience the greatest effects after single overflight incidents. As they become more experienced with the stimulus, the chances of these effects will decline to zero. The economic effect of the responses, i.e. animals dead or lost, will be determined

by differences in temperament (breed and age differences) and management conditions (type of housing and so on).

Experienced animals will not panic, but they will be susceptible to effects due to cumulative exposure. At present we cannot model the potential for loss of productivity because the type of dose-response data necessary to produce such a model are unavailable. However, the basic information necessary to producing such models will be allocated a place in the ASAN system, so that when the dose-response data are available, the models can be implemented quickly. We expect these models to take a cumulative measure of noise dosage, such as L_{dn}, and predict proportional loss of productivity (e.g. percent decline in milk production).

In either case (models of single-incident effects, models of cumulative effects), the error in predictions will be quantified by a series of Monte-Carlo simulations after the model has been implemented, and the results will be included with the documentation for ASAN.

Based on our review of the literature and on the preliminary reviews of the model, the most important gaps in our understanding of animal responses are as follows:

Normal rates of trauma induced by panic are very poorly documented. This means that we cannot put losses of .1% into perspective or predict a priori what types of sounds are most likely to be effective. Both experimental studies of responses and surveys of losses on farms across the country are needed to address this gap.

Possible subtle effects on weight gain, milk yield, productivity, and fertility are either non-existent based on current information or undocumented, although they are frequently the subject of public debate. These effects must be documented using epidemiological studies, as the numbers of animals necessary to study such effects experimentally are prohibitively expensive to maintain. Short studies of "pre-stressed" animals would be useful to determine whether the effects can occur at all, but they will not allow predictions for the rate of occurrence in normal practice.

The relation between the physiological effects of noise and effects on productivity is poorly-understood. At this point, we have sidestepped the issue of physiological effects by looking directly at the relation between overt responses and effects or by looking at cumulative dosage and effects. In the future models can be improved considerably by understanding the physiological basis for any effects on productivity that are observed. However, much basic research is needed to develop the relations between physiological responses (e.g. rise in levels of glucocorticosteroids) and loss of productivity, basic research that is not within the scope of NSBIT.

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This program would not have been completed without the assistance and advice of many people. Col. Dennis Skalka provided us with invaluable assistance in collecting together and interpreting the USAF claims files. The Occupational and Environmental Health Laboratory (OEHL) at Brooks Air Force Base provided logistic support. Five animal health specialists at the University of California at Davis provided us with expert advice on the potential for effects and careful criticism of the report and the literature - they are Dr. Gary Moberg (Department of Animal Physiology), Dr. David Hird and Dr. Ian Gardner (Department of Epidemiology and Preventive Medicine), Dr. Michael Bruss (School of Veterinary Medicine), and Dr. Michael Fry (Department of Avian Sciences). Dr. Francine Bradley (Cooperative Extension Service) and Cindy Book (Department of Avian Science) provided invaluable advice. Without the help of these specialists, this program would not have been possible. Captain Robert Kull (NSBIT) also commented on the plan for this program, making many excellent suggestions.

1.0 INTRODUCTION

Studies have focused on the effects of sonic booms and aircraft noise on domestic animals since the late 1950s (Cottereau, 1972). Originally, these studies were motivated both by public concerns about what was at that time a relatively novel technology, supersonic flight (see, for example, Shurcliff, 1970), and by claims leveled against the U. S. Air Force (USAF) for damage done to farm animals by very low-level subsonic overflights. Since that time over 40 studies of aircraft noise and sonic booms, both in the U.S. and overseas, have addressed acute effects, including effects of startle responses (sheep, horses, cattle, fowl), and effects on reproduction and growth (sheep, cattle, fowl, swine), parental behaviors (fowl, mink), milk letdown (dairy cattle, dairy goats, swine), and egg production. Several reviews of earlier work have been published (e.g., Dufour, 1980; Bell, 1972) but these do not include a number of significant foreign studies, including recent, detailed, work by the veterinary school in Hannover, nor do they attempt to develop a theory for how noise affects domestic animals.

This study was designed to bring the literature "up to date", to develop a synthesis that resolves the conflicts between results of different studies, to specify what types of effects on animals can be expected, and to develop a theoretical model that explains the effects.

The literature on the effects of noise on domestic animals is not large, and most of the studies have focused on the relation between effects and dosages of continuous noise, such as noise in hen houses (Belanovskii and Omel'yanenko, 1982) and miscellaneous human noise (radios, motor noise, etc.; Ames, 1974). Chronic noises are not a good model for aircraft noise, which lasts only a few seconds, but which is often very startling. Instead, we require a dose-response relation to describe what serious consequences may befall an animal that is severely startled at unpredictable, long intervals. This study will develop a preliminary version of such a dose-response model.

1.1 Background and Definitions

Aircraft noise will have effects because it triggers a startle response, a sequence of physiological and behavioral events that once helped animals avoid predators. The physiology of startles has been described in some detail (Ekman et al., 1985; Hoffman and Searle, 1968; Ames and Arehart, 1970; Borg, 1978a,b,c). There are good dose-response relations describing the tendency to startle to various levels of noise, and the effect of habituation on the startle response.

The link between startles and serious effects, i.e. effects on productivity, is less certain. Previous reviews of the literature on domestic animals (Dufour, 1980; Bell, 1972; Bond, 1970) have been vague about the definition of effect, let alone specifying dose-response relations. Here, we will define an effect as any change in a domestic animal that alters its economic value, including changes in body weight or weight gain, numbers of young produced, weight of young produced, fertility, milk production, general health, longevity, or tractability. Although changes in the well-being of animals have also become an important consideration from a political point of view, they are not a part of the EIAP. At this point, changes in productivity are an adequate indirect measure of changes in well-being, at least until objective legal guidelines are provided.

Our focus on the effects on production runs counter to a trend in the literature towards measuring the relation between noise and physiological effects, such as changes in corticosteroid levels, and in measures of immune system function (Fletcher and Blenden, 1986). Although these are certainly ways to measure animal stress (Moberg, 1985), they very often are uncorrelated with effects, possibly because the animal has adapted well to the stressor (Ames and Arehart, 1970; Moberg, 1987a) or because the measure one has chosen does not change in response to a particular stressor (Lefcourt et al., 1986). As a result, it is difficult to determine the relation between dosages of noise and serious effects using only physiological measures. To assess noise impacts, we must first establish the link between noise and effects on productivity; then we can search for physiological correlates. If, as we suspect, sufficient data are not available to develop a dose-response relation

based on physiological correlates, our model will still measure the economically-important relation between dosages and effects on farm output.

2.0 STUDY METHODS

To develop a synthesis for the effects of noise, we reviewed all the available data on effects of noise, analyzed what raw data were available to try to resolve contradictions among the various sources, and created a table showing the probable effects and the best method for measuring these effects in the future. The analysis of the data will be the basis for a simple "straw man" model of noise effects (Section 4.0).

2.1 Methods of Literature Review

To identify the literature on the effects of noise on domestic animals,

1. We obtained all the references from previous reviews of noise effects, particularly Dufour, 1980; Fletcher and Blenden, 1986; Bell, 1972; Fletcher and Harvey, 1971, and Subcommittee on Animal Response, 1970.

2. We searched the electronic bibliographic databases, including Biological Abstracts and Zoological Record, as well as specialized databases, such as USDA's AGRICOLA, and the Cambridge database.

3. We conducted a "backwards" search of all the literature we had found by going through the references in each document.

4. We searched through the records of the USAF at the Occupational and Environmental Health Laboratory (OEHL) at Brooks Air Force Base. We also obtained copies of all the claims against the USAF for damage done to animals.

5. We searched through current issues of veterinary journals and contacted veterinarians interested in the effects of noise.

6. We obtained copies of a whole series of theses done at the School of Veterinary Medicine in Hannover, West Germany. All these studies exposed domestic animals, including pregnant cows and mares, poultry, swine and mink, to extremely low-altitude military aircraft overflights. Although deficient in many respects, these studies represent the only large and coherent body of studies on the effects of noise from low-altitude overflights on domestic animals.

7. We contacted veterinarians about their experiences with animals that have panicked due to a surprise.

2.2 Analysis of Data on Effects

Only a few documents contain adequate information to conduct an analysis and for the most part authors analyzed their own results statistically. We have relied on the author's results where available. In a few cases, we have reanalyzed raw data to examine a different aspect of problem, such as estimating habituation rates, particularly from raw data presented in original reports and theses.

Our analysis consisted of 1) summarizing the contents of the USAF claims files, 2) reanalyzing the data on mortality and weight loss in a few English-language studies (Travis et al., 1972a,b; Stadelman and Kosin, 1957; Winchester et al., 1959), and 3) extracting data on habituation and injury rates from the German dissertations. There were too few studies on any given effect to warrant any kind of meta-analysis of the literature (Glass, 1976).

The specifics of statistical tests or graphical analyses used on each dataset will be given under each subheading. All statistical comparisons were made with the SYSTAT or STATGRAPHICS analysis packages.

2.3 Criteria for Conclusions

Effects were scored with a qualitative measure, probable, possible, unlikely, or unknown. The criteria we used for scoring effects were as follows:

1. It is common to set the criterion for P, the statistical probability of observing an effect by chance alone, to .05 or smaller. In studies of risk effects, however, the criterion is often set at .1 or higher to reduce the chance of rejecting a marginal effect. We have adopted this criterion in our analysis of the literature. Effects significant by this measure are probable.

2. If an effect did not meet statistical criteria but the sample size of the study was inadequate, the effect will be scored as unlikely if well-documented anecdotal accounts suggested it was improbable, or possible if they suggested it was possible.

3. Effects had to be measured by a controlled experimental study or an epidemiological study in which "normal" productivity was well-defined. If the study did not meet these criteria, the effect was scored as unknown. An effect was possible if supported by an anecdote that had sufficient clinical information.

4. Significant effects on hormone levels or other physiological parameters were not sufficient alone to define an effect. They had to be linked to a difference in productivity. If there was no such link, either in well-documented anecdotes or in the results of experiments, the effects suggested were unknown.

5. If the noise studied was not a good model for aircraft noise, the effect was scored as unknown.

6. If the data or claim gave results that were improbable biologically, the effect was scored as unlikely.

3.0 A POSITION PAPER FOR THE EFFECTS OF AIRCRAFT NOISE ON DOMESTIC ANIMALS

3.1 Review of the Claims Against the USAF for Damage to Domestic Animals

3.1.1 Summary of Contents of USAF Claims Files

The USAF claims files at OEHL summarize 248 claims against the Air Force for alleged damages to domestic animals from 1956-1988. According to the staff at OEHL (Skalka pers. comm), minor claims are not submitted to this depository, so the incidence of small claims is probably underestimated in this dataset. However, all the large or controversial claims are archived there eventually.

We reviewed all the claims. Two that were not directly related to Air Force flight activities were rejected immediately, and five that contained inadequate information (i.e. only the amount claimed and name of claimant) were discarded later. The rest were summarized in a database that included the name of the claimant, the date of the claim, the Air Force Base receiving the claim, the nature of the activity, date, time and location of the claim incident, the amount of the claim, the amount paid, the number and species of animal affected, and the type of injuries sustained. Details about all the fields in the database are given in Appendix 1.

With this information, we made rough estimates of the types of activity perceived as causing the most damage, the types of damage reported, the species of animal most often affected, the proportions of animals affected, and the costs to the Air Force of these types of claims. Records were categorized by species, and then were grouped by animal type. "Fowl" included all ducks, chickens, turkeys, quail, and pheasants. "Fur bearers" included fox, chinchillas, rabbits, and mink; "mink" were also listed in a separate category. Parrots and canaries were grouped together as "exotic birds". Deer were listed as "wild mammals" and cougar, lynx, gazelle, zebra, and oryx were labelled "exotic mammals". Other animals were listed by species.

Table 1 lists the numbers and value of claims for each animal type. Over the 32 year span, $3,226,647 in claims were submitted and $782,979 were paid out. By year, around $100,833 in claims are submitted and $24,468 in claims are paid out. Most of this cost may be attributed to a few expensive claims (the two most expensive totaled $772,167, or 22% of the total value of and 62% of the claims paid).

Most claims only specified the number of animals reportedly affected by a particular disturbance; those claims where the number of exposed animals was also given are presented in Table 2. The proportion of exposed animals affected ranged from 32-35% of fur bearers to 72-77% of horses and beef cattle. Thirty to 50% of the fowl exposed were affected. These numbers are overestimates because all animals on the farm were included in estimates of weight loss.

The dollar value of claims was highest ($1,002,400) for fur bearers; however, less than 10% ($77,308) of this amount was approved (i.e., was considered valid by investigators). Losses reported by mink farmers ($911,908 claimed, $76,003 approved) made up the bulk of the fur bearer claims. The dollar amount approved was highest ($485,213) for beef cattle, mostly due to one claim of $395,901 which involved the accidental escape of a genetically-managed herd. Over $158,223 was approved for damage to fowl. Approved claims for other species were all under $24,000.

The small number of claims reported (8 per year from all Air Force bases), in comparison with the hundreds of thousands of miles of flights logged each year by aircraft activities, indicates that damages from overflights are rare. Moreover, many of the claims are of dubious validity according to Air Force reviewers. In economic terms, these claims do not represent a large source of loss in and of themselves. However, from a political point of view they are extremely important. They represent an estimate of economic loss for the EIAP as well.

Claims for damages sometimes came in "runs". The number of claims submitted per year appeared to fluctuate randomly after the 1960s. However, when we examined the distribution of claims by species, it became clear that there were "peaks" over the 32 year period in claims for damage to

several animal types. Figure 1a-c shows the number of claims by year for the animal types best-represented in the claims files, mink, fowl, and cattle. The reasons for these peaks seem to vary, but in several cases (mink, fowl), the number of claims declined abruptly after publication of a government study showing that the effects claimed were baseless (studies of Stadelman and Kosin, 1957; Stadelman, 1958a,b; and Travis et al., 1968, 1972b). Thus, not only is the sample of claims biased by under-reporting of small claims, but it is biased by changes in the expectations of claimants. The "runs" of claims were not brought against any one Air Force Base, but it is possible that they were triggered by the opening of new military training routes and operations areas (MTRs, MOAs) or development of new technologies (supersonic flight). We review the reasons for these "runs" of claims under the discussion for each species in section 3.2 below.

Table 3 shows the numbers of claims associated with each disturbance type. Most complaints were instigated by low-altitude overflights (54% of claims). Sonic booms instigated 33% of the claims overall, and seemed to give rise to a disproportionate number of claims for damages to domestic fowl (41% of claims versus a maximum of 30% of claims for mink, cattle, and horses). Given the biased nature of the data, it is impossible to say whether this difference is significant. It is possible that fowl are more reflexive in their responses to sounds with rapid onsets than mammals. Very little information was available in most claims about the type, number, and altitude of the aircraft causing the damages. Visual estimates of altitude are notoriously unreliable, so we did not attempt to interpret the reports of the farmers too literally. However, it is clear that the flights causing the greatest damages were fairly close to the farms (within 150 m) because the farmers estimated them to be very close, "50-100 ft away".

3.1.2 Types of Damages Reported in the Claims Files

Table 4 lists the claims by type of damage. Generally, escapes, trauma and deaths due to panic were the most common, most expensive and best documented source of losses (71% of claims). Reproductive losses were the second most common complaint, due to a variety of causes, such as aberrant parental behaviors, reduced fertility, premature births and abortions (51% of claims; some

claims included both complaints so the percentages do not add to 100%). Weight loss was the third most common complaint (12% of claims). Other sources of complaint (such as changes in animal or pelt quality) were rare.

The clinical records and eyewitness accounts of injuries and losses after panics usually were good, and we consider this the most important potential source of damages after very low-altitude overflights. Behavioral responses of different species differed somewhat, so they will be discussed under separate headings below. We infer that the animals were naive at the time of exposure to the overflights because owners generally reported a sudden onset of disturbing aircraft activity. However, we have little documentation, even in the best-reported claims, to support this inference.

Reproductive losses after an overflight were usually poorly-documented and speculative. For example, even though mink ranchers submitted claims against the Air Force repeatedly for kit losses after sonic booms and low-altitude overflights, none had any eyewitness or photographic records of mother mink eating their young. Reduced laying rates of hens, abortions in cattle and horses, and abandonment of young or crushing of young by pigs and mink also were not linked incontrovertibly with the aircraft overflights either. In part, such a linkage could be established only after careful experimentation, but even simple clinical records (for example, showing newly-born kits in the guts or feces of female mink) were not provided. Often complicating factors, such as poor conditions on the farm, disease, bad diet, or environmental stress coincided with the overflights, so that causes of reproductive declines could not be established exactly (see Milligan et al., 1983). Weight losses were even more poorly documented. Sometimes, weight losses and abortions were reported weeks or months after the overflight incidents, long after any physiological response to the overflight would have disappeared.

3.2 Review of the Literature on the Effects of Aircraft Activity on Domestic Animals

There are contradictions among controlled studies and anecdotal reports (e.g., claims against the USAF, popular accounts such as Bryson, 1986) and controlled studies. Numerous claims suggest

that catastrophic responses by animals are possible, such as stampedes that result in traumatic damage to many animals (Table 2), yet researchers never see such effects under controlled conditions.

For a long time these contradictions have been viewed as the result of conflicts between the interests of the Air Force, epitomized by the results of studies, and the interests of farmers, epitomized by the claims files. However, we believe there are more neutral explanations for the contradictions. First, and most important, most studies have used habituated animals or have failed to document the previous experience of the animals with aircraft noise. Thus, the study subjects were often unlikely to exhibit extreme responses to noise. Second, most studies have been purely observational and short-term (generally running only a few months) and have exposed only small numbers of animals to a few overflights or sonic booms. Third, they did not measure the physical characteristics of the noise to which animals were exposed. Fourth, when they failed to show any catastrophic effects, the investigators returned a finding of "no effect" instead of attempting to recreate the conditions under which substantial damages had been reported in claims and anecdotal reports; thus, they could not say what happened under "worst-case" conditions. Fifth, effects, when observed, were fairly subtle, and the experiments were not designed to measure small differences statistically. Finally, very few studies were designed to determine the relationship between particular dosages of aircraft noise and serious consequences, such as reproductive losses, decreased weight gain, or trauma due to panic.

Perceived contradictions might arise for another reason. A number of indirect measures of effect, such as behavioral startles, changes in blood flow (Belanovskii and Omel'yanenko, 1982; Falconer, 1965), measures of immune function (Jensen and Rasmussen, 1970; Lefcourt and Capuco, 1989), adrenal hormones (Wildenhahn et al., 1976a,b), and thyroid function (Ames, 1971; Falconer, 1965) have been used as evidence that noise affects animals. However, Moberg (1985, 1987a, b) points out that the use of such measures is frought with difficulties in interpretation because "stress" is not defined by any one set of physiological responses, the animal is often "stressed" by normal physiological processes (such as reproduction), and because it is quite clear that many "stress"

responses are actually adaptive responses that do not affect an animal's health or productivity in any observable way. For instance, a significant elevation of plasma corticosteroids has been regarded as evidence of stress, but it is actually best regarded as an indicator of adaptation to a stressor. Such elevated levels do not imply that an animal's well-being is threatened (Moberg, 1987a), nor do they necessarily correlate with meaningful change in biological function (Moberg, 1987b). The best measures of stress are not the physiological correlates typically measured, but general measures of health and productivity such as weight gain and reproductive capacity.

Given this background, we have analyzed the literature to resolve the apparent conflicts among different reports, including the clinical records in the claims files. Because of the ambiguity of indirect physiological measures of stress such as plasma corticosteroids and heart rate, and because claims against the USAF are usually for production losses, we have focused our discussion on studies that have documented production-related effects of noise such as changes in egg or milk production and damage or loss of animals due to panic responses. Section 3.2 presents pertinent data from the literature on noise exposure and subsequent effects for all types of animals examined (fowl, cattle, horses, sheep and goats, swine and fur-bearers).

3.2.1 Production-Related Effects of Noise on Fowl

3.2.1.1 Trauma (including death) due to panic.

Fifty-six of 101 (55%) claims against the USAF for damage to fowl were related to panic reactions: 24 claims of trauma or death and 32 of smothering due to crowding or piling up (Table 4). The possibility of this effect is supported by two reports in the literature (Table 5). Stadelman and Kosin (1957) and Stadelman (1958a) reported one death out of 2400 due to smothering when 31-day-old broilers reacted violently by crowding and piling up to the onset of four hours of aircraft overflight noise at 120 dB. Crowding (but no mortality) was also observed in 45-day-old broilers exposed to intermittent aircraft noise in the same study. Von Rhein (1983) reported that 1-week-old chickens piled up in response to jet overflights and hovering helicopters; older chicks did not

pile up, and no increased mortality was observed. Cottereau (1972) exposed chicks to high-amplitude simulated sonic booms (up to 130 dB flat peak sound pressure levels) six times per day throughout rearing. Just after hatching, chicks responded to these sounds by crouching and crowding, a natural predator-avoidance response. However, at around the time of fledging the response changed to one of flight (running and flapping), also a natural response. Cottereau's poults were well-accustomed to noise by the time they fledged, whereas Stadelman's were naive. Also, Cottereau maintained his chicks in small numbers (200 or fewer per container), as did Von Rhein. The results of these studies are consistent with the hypothesis that naive poults are most likely to crowd dangerously and that there is an effect of group size on the likelihood of damages. Stadelman (1958a) made a similar suggestion in his discussion of the crowding he observed in his study. He also suggested that there was an effect of age on tendency to crowd. The results of the other studies are not consistent with an age effect, but with an effect of previous experience: naive broilers crowd and pile dangerously, whereas habituated ones do not. If body weight were a factor, an age effect would be expected.

Other reports (Table 5) of deaths caused by noise probably are not relevant. These include increased mortality rates among laying hens (6-8% for 87 and 92 dB noise vs. 3-4% for 55 and 75 dB noise) in a commercial poultry house (Belanovskii and Omel'yanenko, 1982); the noise source in this case was machinery and the noise made by the chickens themselves. Von Rhein (1983) reported the death of a single hen (out of 140) due to a foot injury that may or may not have occurred of after an overflight.

3.2.1.2 Decreased egg production.

There were 32 reports of decreased egg production and 7 of reduced hatchability in USAF claims files (Table 4). Egg breakage and reduced hatchability have not been observed in experimental studies using impulse noise (Teer and Truett, 1973; Richmond unpubl.; Heinemann and LeBrocq, 1965; Cogger and Zegarra, 1980; Cottereau, 1972; Bowles et al., 1990 (unpublished manuscript); Stiles and Dawson, 1961) and theory suggests that such damage may not be possible (Frank Awbrey

pers. comm). There is some evidence for changes in egg production in hens exposed to continuous or frequent but intermittent loud noise (Table 5). Belanovskii and Omel'yanenko (1982), Ivos et al. (1976), and Hamm (1967) reported decreased egg production in chickens exposed to commercial poultry production noise, bells and sirens, and army maneuvers (including air reconnaissance), respectively. Okamoto et al. (1963) reported that laying rate in experimental hens decreased more rapidly than controls in birds treated with continuous sound (jet plane noise) throughout at least one month of their laying periods. These data were not tested statistically. The differences in means were small and the standard deviations were large, so we are skeptical that significant differences were observed. Exposure to continuous light and continuous radio noise caused a disruption of the usual diurnal/nocturnal laying pattern in chickens, and increased the mean interval between successive eggs within a laying cycle; there was no effect on the total number of eggs produced per cycle (Morris, 1961). After 57 days, the noise was discontinued but the hens still laid eggs at any hour of the day, suggesting that continuous light was the cause of the change in laying pattern.

Studies that exposed hens to infrequent intense noise bursts of the sort expected along MTRs and MOAs did not demonstrate effects on hen productivity, however. Stadelman and Kosin (1957) did the most extensive study, exposing 140 laying hens. Von Rhein (1983) did not find any change in productivity either until an accident in the hen house created a water shortage for several days. After this, he reported that laying hens exposed to hovering helicopters consumed their own eggs; a close examination of his records suggests that this behavior was induced by water deprivation because similar noise exposures earlier that same month did not result in egg consumption. Cottereau (1972) also failed to find changes in productivity of hens exposed to 6 sonic booms of over 140 dB (flat weighted) per day. Unfortunately, Cottereau failed to analyze his results statistically and did not present sufficient data for an analysis after the fact.

It seems clear that sudden noise can affect broodiness in hens. Stadelman and Kosin (1957), Stadelman (1958b), Jeannotout and Adams (1961) all report substantial declines in broodiness of hens and turkeys exposed to aircraft noise and sonic booms. It is not clear, however, what dosages

are required or how long these effects last, but they can affect at least one incubation cycle (Stadelman and Kosin, 1957). It is also unclear that these would affect productivity in normal farming operations, since commercial laying hens do not brood their own eggs.

Egg quality has been affected by noise. More blood spots were found in eggs laid by chickens exposed to whistles and "medium loud" radios, although there was no change in other measures of egg quality (e.g., egg weight, shell thickness; Stiles and Dawson, 1961). Okamoto et al. (1963) found a significant decrease in the total weight of eggs laid by chickens exposed to jet plane noise. However, they did not describe their methods adequately and they measured sound levels in a unit of loudness developed for humans, the "phon", a measure likely to have little meaning for chickens. Such effects would be found only within 24 hours of the overflight.

Since the stimuli varied so much from study to study it is not surprising that no clear dose-response relation can be inferred from the literature. At this point, we must consider the effects of aircraft noise on egg quality possible but inadequately documented.

3.2.1.3 Reproductive failures due to other causes.

Although one claim of decreased fertility was made to the USAF, we found little evidence in the literature to support the claim that significant reproductive problems can be caused by intermittent noise (other than the changes in egg quality noted above). For example, high levels of continuous noise had no effect on male fertility (Kosin, 1958), and intermittent noise (95-120 dB) did not affect spermatogenesis (Stadelman and Kosin, 1957). Note, however, that Kosin (1958) reported somewhat lower laying rates in hens receiving sperm of exposed males. The data are insufficient to determine whether this effect is the result of noise exposure or other factors, and Kosin was skeptical that noise caused the difference. At present, we must categorize effects on fertility as unknown, but probably unlikely.

3.2.1.4 Weight loss or failure to gain.

Six claims reported weight loss in domestic fowl, but experimental studies have not detected weight changes due to noise exposure. Stadelman and Kosin (1957) examined this question thoroughly in their document, using many replicates of paired, genetically-matched control and experimental groups. Their sample sizes were adequate to detect an effect if such were to be found. Moreover, there was no evidence of consistently lower weights in the experimental groups, as might be found if the sample sizes or statistics were inadequate to measure a difference. Their chicks were exposed to 6 booms per day at levels ranging from 134 - 168dB (flat weighted). Cottereau (1972) reported no effect on weight gain either, but he did not analyze his data adequately. Documentation in the claims was inadequate, so we must consider weight loss or failure to gain unlikely based on current evidence.

3.2.2 Production-Related Effects of Noise on Cattle

3.2.2.1 Trauma (including death) due to panic.

As reported for fowl, over half (53%, 48 of 91) of the claims against the USAF for damage to beef or dairy cattle are the result of panic-related losses: 47 claims of trauma or death and one of animal disappearance following noise exposure (Table 4). Unlike fowl, which were affected equally by sonic booms and low-flying aircraft, sonic booms represented a very small proportion of the impact on cattle - 36 claims were for damages done by low-flying aircraft versus 7 by sonic booms. Since we do not know how often cattle were exposed to both stimuli, this difference may be a result of artifact. However, it does suggest a hypothesis, namely that cattle are much less affected by sonic booms, a non-specific noise, than by low-flying aircraft, which also present a visual target.

Dairy cattle from the claims appear to be much less susceptible to damages than beef cattle. In the 22 claims for which size of the cattle herd was specified, 77% of beef cattle were reportedly affected, versus 34% of dairy cattle (note that these proportions are for all damages combined,

including weight loss). Although this breakdown includes all effects combined, it suggests that the placid temperament of the dairy cow renders them less susceptible to startle-related damages in general or that the way dairy cows are managed makes them less susceptible. This suggests that breed temperament might be an important factor in determining damages (Table 6). We can say little about breed as a factor because no studies have examined breed-related differences in responses; however, the model described below is designed to include information on breed differences as it becomes available.

The most costly damages were due to escapes rather than injuries. The single most expensive claim ($395,901) was for disruption of a breeding program after carefully-segregated cows broke loose. Such costliness is not unexpected, as one individual breaking a fence can loose and entire herd, whereas trauma, even during a stampede, must strike each individual separately.

The rates of damages in the claims files are certainly overestimates, as claims do not consider the many cases when no damages occurred. Thus, they are only useful as indicators of the relative importance of different types of damage. Absolute rates must be obtained from the reports of studies (Table 7).

The most useful studies are the Hannover theses and Espmark et al.'s (1974) excellent study of sonic boom effects. No injuries were observed in any of these studies. The Hannover cattle (40 cows in three studies) were naive at the time of first exposure, and were exposed to unusually high levels of aircraft activity (approximately 100 overflights in less than two months). One cow pushed her head and foreleg through a fence, the most potentially-dangerous accident observed (Heicks, 1985). Beyer (1983) reported that two of 10 naive, pregnant cows exposed to very low-altitude jet aircraft and helicopter overflights broke through or jumped fences. Thus, the potentially damaging accidents were to one cow of 40 and the escape attempts were by two of 40.

Although all three Hannover studies reported great variability in responses of individuals (Beyer, 1983; Heicks, 1985; Heuweiser, 1982), none quantified response behaviors in any detail, making it

impossible to determine what proportion of cows respond to overflights or how rapidly they habituate. Espmark et al. (1974) provided better information on response rates to sonic booms by calculating dose-response relations with aircraft sound level, rise time, and sequence number (Figure 2a-c), but classified behaviors on a relative scale that does not allow us to estimate potentially-damaging behaviors, such as running, kicking or biting.

Espmark et al. (1974), Bond et al. (1974), and Casady and Lehman (1967) all examined effects on free-ranging cattle that probably had been exposed to aircraft overflights previously. In none of these studies (3 studies of a total 10378 cattle) did any injuries occur, even though sonic boom overpressures approached 140 dB (maximum flat SPL) and aircraft overflight sound levels approached 127 dB. Habituation apparently reduces the chances of damage considerably.

Clearly, the responses most likely to lead to traumatic losses are those of naive animals. The Hannover studies examined small herds housed in well-maintained paddocks, rather than larger herds in varying housing, as is typical of most commercial dairy or beef cattle operations. None of the 40 cattle examined in the Hannover studies sustained any traumatic injuries or losses. It seems clear that the herds that suffered damages in the claims files must have been composed of naive animals, based on the behavioral responses observed, so differences in housing conditions are a likely candidate to explain the difference in loss rates between the Hannover studies and the claims.

We analyzed the reports of cattle injuries and deaths due to trauma and of losses due to escape in the claims files. Table 2 summarizes these data for all herds in the claims and for those herds of known size. Damages were scored as "0" when the farmer reported that his animals did not respond or when no injury or loss resulted from running. Most claims were for deaths since injured animals typically were destroyed.

Combining both injuries and losses, the estimated "worst-case" casualty rate was about 2.2% per herd for the herds of known size that experienced some type of loss, combining dairy, veal, and beef cattle together. These rates are due to first exposures of naive animals, since typically only one or

two sorties were observed. The samples of dairy and veal herds with known herd sizes were not large (2 of each with known herd sizes), so we cannot infer much from the difference in percent casualties between these and beef herds. There were 23 herds altogether in the sample. Herd sizes varied from around 15 animals to 600 in the sample. The mean herd size was 204 head. There appeared to be no relation between number of head lost or injured and herd size in this dataset (Figure 8).

Losses for all herds with adequate records of responses were a median of one per herd (average 4.3 head per herd), with a range of 1-56. The median number of casualties was a fairer representation of the data, as the distributions was heavily skewed to losses of zero or one animals. Only three herds of the 37 had casualties of more than 10 animals (one herd of 350 had 56, one herd of unknown size had 29, and one herd had 11). Note that these values are the outside limit of the damages that are likely and they never exceed 10% of the animals in the herd. In the 32 years for which claims are recorded, only 39 claims for traumatic losses in cattle were filed, or slightly over one per year countrywide.

Housing apparently was an important factor in determining casualties because most of the injuries to cattle in the claims files were due to running into barbed-wire fences, running up against nails or other sharp objects, or breaking legs in falls. Losses typically were due to escapes or to injuries sustained in falls on uneven ground. The authors of several Hannover theses supported this observation (e.g. Beyer, 1983). Barbed wire and poorly-maintained enclosures are most likely to be found in areas with ranging stock (sheep or cattle).

In summary, traumatic injuries and deaths are quite likely to occur occasionally, are most likely to occur when cattle are naive about aircraft, and are likely to occur in small farming situations where housing conditions are more variable. The probable rates of these injuries are unknown, as the claims do not constitute a random sample of all farms exposed to aircraft noise, but are low even in the worst case, averaging around 2.2% per herd. No experimental study of naive or habituated animals has ever observed damages of any kind, so the rate in well-managed farms is much lower,

on the order of .01% (1 in 10000). This generalization holds for the more commonly-held breeds of cattle (e.g. Holstein dairy cows and Hereford beef cattle). We cannot generalize about differences between dairy, veal and beef cattle. More reactive breeds, such as Brahmas, have not been studied, and are not the subject of claims in any event.

3.2.2.2 Decreased milk production.

There were four claims of decreased milk production in the files we reviewed (Table 1), or around 4% of the claims for damage to cattle and 29% of the claims for damage to dairy cattle. This is a relatively small proportion of the claims, and is probably the result of several factors, not the least of which is that dairy farms are easy to avoid.

The effects of aircraft noise on dairy animals have been examined repeatedly (Ely and Peterson, 1941; Parker and Bayley, 1960; Kovalcik and Sottnik, 1971; Espmark et al., 1974; Sugawara and Kazushi, 1979; Broucek et al., 1983; Heuwieser, 1982). In cases where animals have been exposed to continuous noise, effects on milk production are sometimes observed, but studies using occasional, startling bursts of noise have shown no significant effect on either productivity or milk let-down. In an epidemiological study, Parker and Bayley (1960) found a significant decrease in milk production in cattle near only one of eight USAF bases they studied; the authors suggested that sampling problems accounted for the differences observed around this base. Oda (1960) reported decreased milk production in five cattle exposed to noise from speed boat races (72 hours per month for several months); however their sound levels were poorly characterized, their sample size was too small and their exposures too long to generalize this study to aircraft noise. Ely and Peterson (1941) documented only short-term effects on milk let-down when cattle were surprised by exploding paper bags, a better model. In their study milk let-down was inhibited for at most one hour and total productivity was unaffected (Table 7).

Only Parker and Bayley's study was directly pertinent to aircraft overflights, and did not examine effect on individual productivity. Thus, direct effects on milk yield have been demonstrated only

in cases where cattle are subjected to high average noise levels over long periods. The evidence to date indicates that effects due to aircraft noise, if any, will be relatively subtle.

To try to understand the possible effect on milk production of surprising a dairy cow at unpredictable intervals, we reviewed several studies that examined effects of another startling stimulus, direct electrical shock to the udder, on behavior and productivity (Lefcourt et al., 1985; Lefcourt et al., 1986). While it is not possible to compare directly electrical shock and surprise in response to noise, the two share some properties: they stimulate strong behavioral responses (kicking, jerking and moving), they elevate the heart rate, and they arouse changes in the levels of some adrenal hormones.

Dairy cattle are subject to such small electrical shocks from "stray voltages" in their environment, small neutral-to-ground potentials from power lines, because their tissues are much less electrically resistant than most animals. These shocks have been said to reduce productivity of dairy cattle (Norell et al., 1982). Lefcourt et al. (1985) subjected 13 dairy cows to intermittent, mild electrical shocks during preparation for milking and milking. "Mild" was defined as shocks that aroused some responses, but did not cause the cattle to break away (6 mA). One cow reacted violently to the shocks, and had to be removed from the study. The rest were tested for 7 days and did not vary with pre- and post-shock periods in milk yield, milking time, or mastitis test scores. The authors concluded that startling electrical shocks would not affect milk yield if dairy producers took care to "accommodate" behavioral responses (kicking, moving). They reported also that cows habituated to the stimuli, and that applying teat cups preparatory to milking had a calming effect on cows while they were being shocked.

A second test determined that these mild shocks did not excite strong glucocorticoid responses. Lefcourt et al. (1986) subjected 7 Holstein dairy cows to increasing levels of electrical shock applied directly to the udder. Two of the cows (29%) responded with unmanageable behaviors (kicking and moving). These cows showed some increase in epinephrine levels but glucocorticoids, prolactin, and norepinephrine remained unchanged. The rest showed no glucocorticoid responses. These results

agree with those of Beyer (1983), Heuweiser (1982), and Heicks (1985), who showed that glucocorticoid responses to aircraft overflights declined as the animals became habituated.

While we cannot compare sound and electrical shock directly, these studies demonstrate that behavioral responses are the most serious consequence of intermittent startles, that these responses are not necessarily linked to physiological responses, that milk let-down is not interrupted by mild startles that do not cause unmanageable movement, and that dairy cattle are capable of habituating even to physically painful stimuli. They also demonstrate that a small proportion of animals are prone to relatively greater reactivity than most (3 of 20 in these studies, or 15%).

The results of these studies, Ely and Peterson's (1941) and Parker and Bayley's (1960), suggest why claims of serious impact on milk productivity of dairy cattle from startles are rare. Claims that have been submitted legitimately may be a secondary result of trauma due to panic. In the claim involving the greatest loss, a farmer's cows plunged out of their enclosure after an overflight, and "many" suffered trampled teats and udders. The cows later suffered productive losses and mastitis (a disease which is nearly gone from commercial dairies now). The claim was allowed because the cattle had suffered trauma, but the lowered milk production could not be linked directly to fright.

Because the link between rare intermittent startles and lowered productivity has been explored without significant result, any but the most transient loss of productivity due to aircraft overflights seems unlikely.

3.2.2.3 Reproductive failures.

There were five claims against the USAF for abortions in cattle (three for beef cattle, two for dairy cattle) as a result of noise exposure (Table 4). Thus, relatively few claims were for abortion. Losses apparently were small within herds that suffered abortions, as well. In two, losses were unknown; for the others, losses were 3/64 [5%, Claim 60-03], one [herd size unknown, Claim 73-04], 15/512 [3%, Claim 85-06]. Such loss rates are typical of most cattle herds.

Table 9 summarizes the rates of abortion in the Hannover studies. All of them examined the possibility of abortion due to frights induced by aircraft. Beyer (1983) saw no interruptions of the pregnancies of ten cows exposed to various aircraft overflights, even though two of his cows panicked and jumped over fences. Heuwieser (1982), on the other hand, reported two stillbirths and one abortion among ten pregnant cows exposed to the same types of aircraft; he felt that the two stillbirths could definitely be attributed to specific overflights, but the cause-effect relationship for the abortion was less clear, as two of the losses were due to disease and as hormonal analyses failed to show any systematic changes in hormone levels that might have led to reproductive failure. Some of his cattle were diseased (Table 9). Heicks (1985) also observed large numbers of abortions and premature births (10 of 20 cows), but only one could not be explained by other causes, chiefly disease.

Results of studies on diseased cattle must be considered suspect. Since the exposures to aircraft were short-term (lasting less than two months), it seems unlikely that the cows could have become diseased as a result of exposure to aircraft overflights. It is much more likely that the herds in these studies were compromised by disease at the time of the studies. Unfortunately, none of the studies compared experimental cattle with a control group, so little can be said about the abortions observed. Certainly, it is impossible to fix the blame for the high abortion rates on overflight. Note that the high rates of abortion observed in these studies are never observed in the claims, a surprise considering that the claims consist of only the most serious effects.

In the case of most claims, damages were observed after single sorties, whereas the cattle in the Hannover studies were exposed to repeated overflights (59, 81 and 117 flights at 50 m or less). Thus, some dosage effect might be hypothesized. However, hormone profiles taken simultaneously with overflights did not suggest any consistent decline in progesterone after overflights that might have suggested a mechanism for the effect. Moreover, there was no observable relation between date of these repeated exposures and lag time to abortions (results of Heicks' study, $N = 20$, Kruskal-Wallis test statistic = .0016, $P > .1$). If dosage effects were present, they were highly non-linear or were masked by disease effects completely. Cows that aborted were not further along in

their pregnancies either (Heicks' and Heuwieser's data combined, ANOVA, N = 30, F = .096, P > .1.

Other studies did not attempt to document effects of startles on pregnancy. Because the rates in the claims files were so low and because the Hannover studies were flawed methodologically to the point of being uninterpretable, the chances of abortions in cattle due to overflights are unknown.

3.2.2.4 Weight loss or failure to gain.

The second most common effect claimed (24%, 22 of 91 claims) was weight loss in affected beef cattle. In each case, cattle were startled by low-flying aircraft and subsequently ran or escaped. The farmers claimed that panic and activity caused the cattle to lose weight or to gain poorly, resulting in lower weight at slaughter.

We are skeptical about the aircraft noise as the cause of weight loss directly because there is no experimental evidence that there are changes in either weight gain or feed consumption in domestic animals after a short scare (as opposed to handling), whether due to noise or to other sources. Slaughter generally tales place long after the incident, making other explanations for lower weight possible, and the farmers did not estimate the weights of their animals by any objective method after the incident or at any time prior to slaughter. Moreover, many of the claims for weight gain contained skeptical reviews by the consulting veterinarian. The only apparently-legitimate cases were those in which stock escaped and travelled on their own for some time before being recovered, in which case exercise and starvation during the period the cattle were missing are more likely to explain the loss than being put "off their feed" by fright.

Evidence for the effect was always very vague in the claims files. For example, "some" of 47 beef cattle had to be sold because they "never recovered from the fright of all the traffic" and "the rest lost weight" (farmer did not specify how he knew; Claim 60-08). In some cases what little supporting data they provided suggested other causes or at the very least, pre-stressed cattle. For

example, Claim 78-02 suggested that most of 253 calves that broke out of a feedlot failed to gain weight after the overflight incident. However, 34 of them died of pneumonia after the incident, a common consequence of the stresses imposed on calves when they are transported to feedlots (Michael Bruss, U.C. Davis pers. comm) after weaning.

The only studies that treated feed intake and weight gain were of ponies (Bond et al., 1974) and sheep (Ames and Arehart, 1970). Ames et al. exposed their sheep to frequent noise of varying amplitude and found very non-linear effects on weight gain (see section on sheep and goats below). However, their sheep were habituated and the study examined consequences of chronic noise exposure rather than effects of single, frightening incidents. Bond et al. found no effect of exposing naive ponies to two sonic booms, either in feed intake on in animal health. Neither study is really an adequate examination of the problem, as animals were not severely frightened in either case. At this point, we must consider effects of aircraft overflights on weight gain in confined and uninjured animals unlikely, as there is no good evidence for the effect either in the published literature or in clinical records from the claims files. In cases where stock escape and roam after being startled, weight loss is possible as a secondary consequence of the escape.

3.2.3 Economic Effects on Horses

3.2.3.1 Trauma (including death) due to panic.

Over 84% (32 of 38) of the claims against the USAF for horses are due to panic responses: 31 claims of trauma or death and one of animal disappearance as a result of noise exposure. Panic rearing, wild running, trampling other animals, and running into barriers caused most of this damage. In 26 of the claims the number lost or injured was specified, with an average of 1.5 horses lost per herd claimed. Note that this is not a fair estimate of potential loss, as exposures that did not result in losses were not reported at all in the claims files. In 20 of the 32 claims (62% of the cases) one horse was lost. The small loss per herd is not unexpected, as horses are typically kept

in small groups (a few riding horses kept at a farm or in a paddock). Sizes of 8 herds were specified, with a mean of 3.5 horses per herd.

Most claims involved the loss of the horse, either to accidental death or to injuries severe enough to warrant destroying the animal. As in the case of cattle, the incidents were rare (around one per year from all MTRs combined). This involved a loss of 1.22 horses per year as a result of all low-level aircraft activity across the country, a small loss by comparison with other sources of accidental death in horses. The information available in the claims files is inadequate to determine whether some breeds are more susceptible than others.

Most losses (15/26 claims) were due to collisions with obstructions (impaling on sharp objects or barbed-wire fences, or breaking limbs against fences or stall walls). Trampling (3/26 claims) and falls (2/26 claims) were rare. The published literature (Table 10) suggests that these damages are largely a consequence of dangerous housing conditions (poorly maintained fences, barbed wire fences, uneven ground), and to naivete of the exposed horses. Both Krüger (1982) and Erath (1984) reported increased aggression (biting, kicking) and intensive escape attempts by pregnant mares in response to the first few exposures to very low-altitude (50 m or lower) aircraft overflights. None of the horses in either study was injured but the authors suggested that accidents and trauma might have occurred in poorer holding facilities or if the mares had been restrained and unable to flee.

Some horse breeds are known to be more nervous and excitable than others (Table 6), but these authors had only small samples of each breed, so it was impossible to look for breed-related effects. These effects are most likely to change habituation rates, as all the mares in these studies exhibited strong fright responses but were eventually able to habituate to the overflights, even helicopters hovering 50 feet over their heads.

Based on these data, and in agreement with common knowledge, trauma due to panic can occur after an overflight in naive horses. The incidence of such losses is still unclear, but is likely to be low. Young horses seemed to be most susceptible probably due to lack of experience.

3.2.3.2 Decreased production.

As horses are not frequently sold by weight, weight related losses have not been reported. Only one case of decreased production has been reported. A farmer was unable to sell rodeo horses for as high a price after his herd escaped and wore themselves out by ranging just prior to sale (Claim 58-01). In one other case losses were incurred because horses did not behave as expected immediately after the overflight (Claim 71-02). Since only two such claims were reported between 1957-1988, such effects must be considered rare, the result of unusual and unpredictable accidents.

3.2.3.3. Reproductive failures.

There were four claims for reproductive failures in horses, three for abortions and one for decreased foal production (Table 4). Two of the abortions were a result of trauma to the mother, and would most appropriately be classified as traumatic losses. Another abortion probably was not related to the aircraft overflight, as the abortion occurred months after the incident. Thus, the evidence in the claims for abortions induced by fright after aircraft overflights is slim.

Two of the Hannover studies examined effects of aircraft harassment (very low-altitude flights, hovering helicopters) on pregnant mares (Table 9). Although Krüger (1982) and Erath (1984) documented changes in plasma hormone levels throughout pregnancy, they could find no concrete evidence of consistent effects. They did suggest that changes in estrogen and progesterone levels were caused by aircraft activity, but these changes apparently did not affect gestation (also in the discussion section of both theses). We found no published reports that documented reproductive losses in noise-exposed horses.

Because the claims files and the experimental work are in agreement, the prospect of abortions in aircraft-exposed mares is unlikely. However, in all fairness, the Hannover studies of effects on horses were flawed to some extent, as there was no control group for the mares in either case. Two abnormal terminations were observed in Erath's study, neither of which could be linked to the

overflights, but without a control group, it is difficult to say whether these losses were normal or not. This deficiency is not a great cause of concern, as loss rates in mares generally run around 3-4% of pregnancies, and the loss rates observed in both studies combined are close to this rate. Thus, Erath's losses are probably a result of other chance factors.

3.2.4 Production-Related Effects on Sheep and Goats

3.2.4.1 Trauma (including death) due to panic.

As for cattle and horses, trauma due to panic was the major cause of claims for damage to sheep and goats (4/8 or 50% of claims; Table 4). Since the number of claims for damage to these animals is small, little can be said about proportions of animals affected and the major causes of damage. In fact, most claims provided little or no specific information on the damage. Number lost was known in only two cases. Two sheep were lost in a panic due to an overflight in one case; in another, a sonic boom caused 23 sheep to bunch up and bloat (Claim 86-03). The latter loss was not supported by sufficient clinical information.

Table 11 summarizes the results of studies on the effects of noise on sheep and goats. Espmark et al. (1974) found that sheep exposed to subsonic and supersonic overflights bunched up and ran as a group, although no accidents or injuries were observed. These animals probably had been exposed to sonic booms and jet overflights before, although none as intense as those produced during experimental conditions. Espmark et al. (1974) measured the relation between sound level and rise time and the reactions of sheep. Unfortunately, they chose a variable definition of "intense" responses, based on the behavior of the sheep at the time of exposure. As a result, it is impossible to determine how many sheep ran in response to the overflights (some as low at 50m).

3.2.4.2 Decreased milk or wool production.

No claims were made against the USAF for decreased milk production. Only one paper treats changes in milk production of goats after noise exposure. Sugawara and Kazushi (1979) concluded that noise decreased daily milk yields in four of five dairy goats exposed to noise (including jet noise). The goats were exposed to a 3 kHz tone and to highway noise, talk over radios, and jet noise varying in level from 65-98 "phons", a scale of measurement based on human loudness perception. Goats were exposed 50% of the hours (one hour on and one hour off) for two days. Eight such experiments were performed over a 100 day period.

We are skeptical about the validity of the conclusions that noise caused milk production to decline and their generalizability to aircraft overflight noise. The goats were exposed to a variety of sounds and sound levels over the eight experiments, so it is difficult to determine which noise may have caused the effects observed. Milk yield was measured two days before, during and after the experiments. There were no control goats observed (goats were used as their own controls). All five goats showed a generally declining milk yield over the course of the study, as expected. Declines on the days of experiments were small relative to overall production and the authors did not analyze the differences statistically, nor did they provide numerical data for all animals. From their graphical representation, the "declines" observed were actually a part of the normal decline of production throughout lactation; productivity did not rebound during long intervals between experiments. Thus, it is difficult to determine how the authors concluded there was a significant decline.

We measured increases and decreases from the raw data provided. Milk yield on experimental days was expressed either as an increase or decrease relative to the pre- and post-experimental periods (Table 12). Based on our qualitative analysis, the trend was exactly what would be observed if there were a mild decline throughout lactation, regardless of the experiments (the differences were not significant). The authors provide some relative differences (their Figure 4), but these values do not agree well with their own figure showing daily productivity. The greatest difference they reported

was 60 ml (out of roughly 1000 ml, or 6% maximally). The greatest positive difference was also 6%. If we sum the values provided in the author's figure, cumulative declines of 70 ml (14ml/goat) were observed the previous two days, 315 ml (60ml/goat) during the experimental days, and 136 (27 ml/goat) in the following two days. At worst, then, the decline in productivity was about 30 ml/day during the experiments, or 3%, after exposures much greater than are likely from any military overflight activity. The authors did not determine whether this difference was statistically significant and we could not see evidence that it was. Based on this experiment, evidence for declines in milk production after exposure to jet noise is weak. Thus, we consider effects on milk production from normal military training activity unlikely.

There was one claim for decreased wool production (Table 4; Claim 87-00), but we did not find any such reports in the literature. This claim was poorly substantiated and probably not legitimate.

3.2.4.3 Reproductive failures.

There were no claims nor published reports of noise-induced reproductive problems in sheep or goats. However, Ames (1974) reported significant increases in the number of corpora lutea and in the number of lambs born to ewes exposed to various types of continuous noise at intermediate levels (100 dB). Since the noise exposure in this experiment was continuous it probably is not a good model for aircraft noise.

3.2.4.4 Weight loss or failure to gain.

There were two claims of weight loss, one for sheep and one for goats, in the USAF files we reviewed (Table 4). Published reports, however, suggest that some types of continuous noise may enhance growth. Ames and his co-workers (Ames and Arehart, 1971; Ames, 1974; Ames, 1978) reported that weight gain and feed efficiency significantly increased in lambs exposed to two noise types at 75 dB. Harbers et al. (1975) found the following digestive responses to various noise treatments: decreased dry matter intake and urinary creatinine, increased digestibility coefficient

and metabolizable energy. At high continuous levels (90 dB and over), weight gain was reduced. However, these continuous exposures are a poor model for intermittent, startling aircraft overflight noise, and little can be concluded about aircraft noise from this. The effect of noise on sheep and goat weight gain is unknown.

3.2.5 Production-Related Effects of Noise on Swine

3.2.5.1 Trauma (including death) due to panic.

Six of 15 (40%) of swine losses claimed against the USAF were the result of panic: three claims of trauma and three of death (Table 4). Documentation in these claims was often poor. In two cases, there was some information on the cause of loss. Not unexpectedly, losses were due to collisions with barricades: in Claim 80-01 one sow died bumping against her pen; in Claim 83-01 an unknown number stampeded and injured themselves.

There are no published reports of injuries caused by panic responses to noise in swine (Table 13). Winchester et al. (1959) attempted to induce such panics in pregnant and recently-farrowed sows by exposing them to a variety of loud sounds (90-120 dB, weighting unknown but presumed flat). Table 14 shows the proportions of behavioral responses to these sounds (tone bursts, tone sweeps, white noise bursts). In no case did sows panic within their enclosures and injure themselves or their young. The sows in these experiments apparently were naive, and they did exhibit startle responses (standing up, searching their quarters), but they did not react violently enough to cause damage. Piglets crowded 13.5% of the time, but none were suffocated or crushed by their mothers. No piglets were consumed by their mothers, as was alleged in the claims.

One of the Hannover theses attempted to induce panic in naive swine as well. Schriever (1985) exposed 22 pregnant sows to 108 overflights of jet aircraft and helicopters. The swine were housed in enclosures at the time of exposure, as is the typical case nowadays, so they could not see the aircraft. The sows had been stressed prior to exposure by being transported, apparently a

potentially-severe stress because one sow died in the process. However, they were acclimated to their enclosure at the time of the overflights, and Schriever found no panics, injuries, or attacks of sows on young. The sows were exposed to sound levels as high as 115 dB from hovering helicopters.

Increased mortality due to continuous noise exposure has been reported in swine, but in this case it is unlikely that the damage was caused by panics, rather by some type of physiological or psychological stress. Ivos and Krsnik (1979) reported that swine exposed to continuous noise levels of 112-121 dB had higher mortality rates than non-exposed animals. There was a dose response relation between noise levels and pigs lost over the range of noise tested (55 dB to 120 dB). However, this noise was a very poor model for occasional aircraft overflights, consisting of continuous radio and machinery noise.

Thus, the bulk of the evidence indicates that panic reactions in swine due to aircraft overflights are likely to be rare. Neither of the experimental studies was able to induce even panic behavior (running or aggression), even though the experimental animals were naive. It may be that the visual image of the aircraft induced the panic behavior reported in the claims. A few swine operations still keep their animals out-of-doors, and at least one of the claims suggested that the affected pigs were housed together in a yard at the time of the overflight.

Thus, we consider losses in swine kept in confinement to be unlikely, whereas they would be possible in open operations. It is impossible to estimate the rates of outdoor losses, as the data in the claims are inadequate.

3.2.5.2 Reproductive failures.

Unlike losses in large stock, the greatest number (7/15, 47%) of swine claims were for reproductive losses; these included abortions, trampling young, and decreased piglet production (Table 4). The losses reported were often substantial: four sows aborted and 59 feeder pigs were lost (Claim 80-

01), 375 fewer piglets than expected were born due to "complications" in labor (claim 81-01), three sows killed or crushed their piglets (Claim 81-05), two sows died and the owner estimated 25 piglets lost (Claim 84-06), and an overflight caused stillborn piglets and piglets with shakes to be born of five sows (Claim 85-11).

Pigs share with fur bearers (and carnivores in general) the tendency to eat abnormal or dead young, at least according to popular claim. While this tendency is poorly documented from any cause in the technical literature, it is a common complaint in claims. Whether this behavior occurs at all is controversial; we will discuss it in more detail in the section on fur-bearers (3.2.6 below). In the claims files, this behavior has not been observed, only inferred from finding dead young that have been partially eaten by their mothers or by smaller than expected litters. If young are stillborn, sows will attempt to eat them, so such findings are not necessarily conclusive.

Neither experimental study on swine reported any losses due to crushing or killing of young (Winchester et al., 1959; Schriever, 1985). Both studies used naive sows. Winchester et al. exposed 23 sows to loud tone bursts and sweeps (they did not have the equipment installed to examine aircraft noise as yet). They observed the sows throughout the exposure period and found no evidence of any aggression toward the young or any panic thrashing within the enclosure. One female carried her young for a short distance; this normal maternal behavior could easily be misconstrued as an attack on the young if the female was not monitored closely.

Schriever exposed 22 pregnant sows and saw no panic thrashing or injuries due to 108 exposures to low-flying aircraft. He also monitored reproductive hormones during the experiments and success of the sows (which were transported to and from the experimental site before farrowing). One sow was lost in transport, one lost her young when a boar attacked her, and one aborted her young to unknown causes (not disease related) long after the overflights. Levels of estrogens and progesterone did not vary consistently with exposure to overflights.

Schriever was skeptical that the one unexplained abortion was caused by the overflights. In addition, the experiment was not conclusive for several reasons. First, the sows were transported, a stress that may have complicated the results. Second, Schriever did not have a set of control sows that underwent transport (or indeed any controls), so the single abortion may not be abnormal. The numbers of young born dead and alive were comparable to values reported in the literature. In the 17 normal farrowings, mean number born live was 9 (sd 2.8), and mean number born dead was .64 (sd .7). This agrees with values given elsewhere.

Thus, there is no experimental evidence that even naive swine either abort or kill their young in response to aircraft overflights, despite two independent attempts to examine the possibility. The claims of such damages are poorly documented, providing no conclusive clinical evidence that damages occurred due to any cause other than trauma. We consider these effects unlikely.

3.2.5.3 Weight loss or failure to gain.

Although one claim of reduced animal quality was filed for swine (Table 4), we found no reports in the literature of weight loss or failure to gain as a result of noise exposure. Algers (1984) noted changes in parental care (suckling behavior) in sows exposed to two days of continuous fan noise (85 dBA). These sows initiated and terminated fewer suckling bouts than control sows. The author suggested that the piglets were getting less milk from the sows, and therefore were hungrier and more likely to initiate nursing. They did not weigh the piglets, however, so there is no evidence of differences in weight gain, and none of the piglets died. Continuous noise is a poor model for aircraft noise, so the study is not really pertinent. At this point, neither the claims or the experimental evidence are adequate to determine whether pigs lose or fail to gain weight when startled intermittently. The probability of effect is unknown.

3.2.6 Production-Related Effects on Fur-Bearers

3.2.6.1 Trauma (including death) due to panic.

Seventeen of 77 (22%) claims for fur-bearer losses (11 of 55 for mink) were for trauma or death due to panic (Table 4). As in the case of swine, these represent a small proportion of the claims, in contrast to the case for large domestic stock.

Neither of the two experimental studies support the idea that mink can be lost to trauma (Table 15). Travis et al. (1972b) examined the responses of 148 1-2 year old mink females and 1845 kits to two sonic booms and other impulsive stimuli (dynamite blasts) and did not observe any responses that might have led to the death of adults or young (Table 16). In this case, the mink were obviously habituated to impulses, as they were exposed to traffic noise, light aircraft, gunshots and dynamite blasts regularly. A sample of the females was observed throughout for evidence of attacks on kits or other dangerous responses. None were observed although the females were exposed to impulses of over 140 dB (maximum overpressure), both from aircraft overflights and a simulator. Brach studied the effects of very low-altitude military jet aircraft overflights and helicopters hovering on 48 farm-raised mink. In this case the mink were naive. The most common response was withdrawal into the nest box, where females apparently felt safe. None were damaged traumatically.

Unlike large animals, which may damage themselves in collisions, it is difficult to imagine how a small animal like a mink could damage itself in a panic. Only dangerous projections in the housing could give rise to such an effect. This type of damage is thus possible but not probable, and it is not documented in any way in the experimental literature.

3.2.6.2 Reproductive failures.

The question of noise effects on fur-bearing animals was hotly debated in a series of claims made against the USAF in the late 1960s, prior to the publication of studies by Travis and his coworkers

(1967, 1972) on ranch-raised mink. As shown in Figure 1, there was a "run" of such claims. In swine, by far the largest number of these claims were for noise-related reproductive losses (45/77, 58%), including abortions (seven claims) and death of kits due to aberrant parental behavior (45 claims of females killing or eating young, three claims of females abandoning young). Most of these claims (71%) involved mink.

The contradiction between what is reported in the claims and what is observed in the experimental literature is greatest for these claims. Moreover, the documentation in the claims is not good, even though they were numerous. Usually, the farmer counted the number of young during the whelping period after an overflight or a sonic boom, and if the numbers were not as great as expected, the loss was attributed to the overflights. Occasionally, the remains of young were found in enclosures, but these may have been eaten by mothers for other reasons, as none of the killings was observed directly.

Most claims for this type of damage were disallowed by the examining veterinarians because the evidence for the effect was so poor. Although farmers claimed over a million dollars for damages to farm mink, only 8% of this amount was paid.

The experimental literature does not support the claim that fur-bearers destroy their young when disturbed by a non-specific stimulus such as sonic booms or aircraft overflights. The earliest of these, a series of experiments by Travis and his coworkers (Travis et al., 1968, 1972b) examined the effects of sonic booms on kit production at a Great Lakes mink ranch, and (after failing to find substantial effects), on mink with a genetic predisposition to stress (Aleutian strain mink; Travis, 1972b). The exposures were typical of the exposures in the claims - a few sonic booms of high level striking the mink unexpectedly. In the first series of studies, mink were exposed to 8 sonic booms per day for 10 days. Levels approached 130 dB (max overpressure). Sonic booms were produced by a simulator. One-hundred and sixty-three pregnant mink were exposed just prior to whelping, and 94 mink were kept under the same conditions as controls. The authors found no significant statistical difference between control and experimental groups in litter size or kit mortality.

The experiment was repeated with the stress-sensitive Aleutian strain when half were ready to whelp and half had just whelped. One group was exposed to two real sonic booms, another to two simulated sonic booms, and another was kept as a control. In addition, some of the exposed animals were exposed to an unplanned dynamite blast. Mothers were monitored on videotape during the experiments. No statistically significant differences were found between the groups in numbers of kits produced, kit weight at pelting, or pelt value. Mink were exposed to sonic booms of higher level (140 dB for sonic booms, and 130 dB for simulated booms) than in the previous study.

In the second experiment, no kits were killed by their dams, no panics occurred, none of the mink were injured and there was no behavioral evidence that mothers were particularly stressed. Table 16 shows the proportions and rates of behaviors observed on videotape. In two cases (of 60 females) mothers carried their young into the nest box, and one female screeched briefly (a behavior indicative of fear in mink). No harm came to the kits that were carried, but this behavior could be misconstrued by an inexperienced observer as an attempt to eat the young. Mink startled briefly after the exposures and then returned to their previous activities.

Although these experiments were well-planned and scientifically sound, they were flawed in one respect: the mink were obviously habituated to impulsive sounds from dynamite blasts and gunshots, which were common in the area during control observations. Moreover, the type of stress-syndrome that the strain develops is unlikely to be produced by three isolated exposures (see the ASAN review of this document by G. Miller, document 4207).

A later study examined the effects of low-altitude overflights on mink productivity (Brach, 1983). Mink were exposed to jet and helicopter overflights (36 overflights at sound levels up to 121 dB). Mink were in runs but had access to covered nest boxes, so they could see the aircraft in some cases. Brach examined female fertility, numbers of young born, numbers of still or premature births, and duration of gestation. A control group and an experimental group were examined. Brach found that the experimental group was somewhat more successful than the controls (although

not significantly so), apparently due to a difference in the handling of the control animals. The only significant difference found was a slightly accelerated (2-3 day) whelping period, which did not seem to affect litter size, numbers of stillborns, or number of fertile females. The mink in this study were naive at the start of experiments, and some running around was observed during the first series of experiments. However, there were no traumatic damages to mothers, and no cases of kits killed or crushed, even though the exposures were intense, long (.5 hr), and lasted over a period of nearly a month.

We cannot conclude from either series of experiments that mink damage themselves or their young after exposure to aircraft noise, either sonic booms or low-altitude overflights. Moreover, exposures (at least the short-term, intermittent exposures that were used in these studies) appeared to have no effect on reproductive success, either female fertility or kit survival.

There has never been any systematic study of the problem of disturbances to whelping mink, whether due to human intrusion or other causes, but the popular literature on fur-bearers is full of reports of females eating their young. Usually, it is caused by an intruder, such as a caretaker, entering the pen or nest box. Gunshots, backfirings, light aircraft overflights, dynamite blasts, etc., are not listed as stimuli that can induce females to eat their young. There are several reports in trade journals that suggest sonic booms can have such effects, but the documentation in these reports is similar to that in the claims files. Apparently, they repeat what appeared to be a popular but unfounded concern during the period when sonic booms first became common.

There is an alternate explanation for the damages observed during this period. Around the time of most of the claims (1960s), a serious toxicological problem was discovered at mink ranches in the north central United States and Canada, where most of these claims originated; the Great Lakes fish that for many years had been used to feed the mink was found to be heavily contaminated with PCBs (Aulerich and Ringer, 1977). Mink are extremely sensitive to PCBs and experimental feeding trials documented dramatic reproductive losses, including failure to whelp, increased numbers of stillbirths, and increased kit mortality (to 100%) for females fed contaminated Great Lakes fish

(Aulerich et al., 1973; Aulerich and Ringer, 1977; Hornshaw et al., 1983). There was also increased mortality of adult mink exposed to dietary PCBs (Aulerich et al., 1986, 1987). For a long time, farmers were unaware of the contamination, and out of ignorance could have blamed disturbances, such as overflights, for the losses.

None of the claimants looked for evidence of contamination, so we cannot say conclusively that this was a factor in any case, but it is a much more reasonable cause than mysterious and abnormal parental behavior that cannot be observed in objective tests. Certainly, no more claims for damages to mink should be allowed unless the animals have been checked for signs of organochloride contamination.

In summary, there is no concrete evidence that females consume their kits after a startle or abort more frequently. These effects must be considered unlikely, especially since other more reasonable hypotheses are available.

3.2.6.3 Weight loss or failure to gain.

There are no claims against the USAF for weight loss or failure to gain in fur-bearers, although there were three claims of decreased pelt quality (all for mink, Table 4). Exposure to dietary PCBs has been shown to cause significant weight loss and failure to gain, and has disrupted molt in experimental mink (Aulerich et al., 1986, 1987). These claims all fall within the period when organochloride poisoning was most likely to be a problem and no attempt was made by any of the claim investigators to determine the source of the losses. The claims were disallowed.

Travis et al. (1972b) examined the problem of kit weight gain in exposed versus control groups. They found no differences in weight gain between the groups except during one month (Table 17). This difference disappeared later, and no significant statistical differences were found in weight at sale or pelt quality. Most of this difference was explained by differences between the groups in the age composition of females. Exposure to noise did not explain any of the differences.

Given that few claims suggested this effect and that experimental evidence indicates it does not occur, we consider the effect unlikely.

3.2.7 Further Analysis of Trauma-Related Effects on Domestic Animals

In the analysis outlined above, indirect effects such as abortions or weight loss due to startles (unless animals traumatize themselves) are not observed. Interestingly, much research effort has been expended on these problems instead of on trauma, although trauma is an equal or larger source of economic loss in fowl and large domestic stock and is an easier problem to study.

We identified several deficiencies in the existing literature. First, even though traumatic damage was frequently cited in the claims, there is little published information on traumatic losses in general. For example, although most of the economic losses in claims for damage to fowl were due to piling and crowding, the incidence of losses due to this behavior are essentially unknown. Apparently, the problem is uncommon enough in commercial operations that it has not been quantified (McCapes pers. comm). Although the excitabilities of different strains of domestic animals have been quantified to some extent (Table 6; Hart, 1985; Hart and Hart, 1988), the tendency to panic due to noise has not. Thus, it is difficult even to predict which animals or strains of animals will be most susceptible.

In addition, little investigation has centered on habituation to non-specific stimuli such as loud noises. Since habituated animals appear to respond only slightly to aircraft overflights, and do not sustain traumatic damages, this habituation process is obviously of importance.

The Hannover theses and some of the published reports contain sufficient information to describe habituation, at least preliminarily, and also to determine the relationship between exposures and losses (also preliminarily). We can describe habituation in horses and dairy cattle, although loss rates in large stock are difficult to estimate because none of the controlled experiments has ever observed such damages, but we can use the incidence of dangerous behaviors (attacks, escapes and

collisions) to provide a crude worst-case estimate. We can also describe losses in domestic fowl, based on data both in the claims and in the published literature.

3.2.7.1 Description of habituation in large domestic stock.

3.2.7.1.1 Responses of horses and cattle from the Hannover studies. Only one of the studies we identified measured the relation between sound level (or other features of the overflight stimulus) and the behavioral responses of large animals (Espmark et al., 1974). However, the animals in these studies had been exposed to aircraft overflights in the past to some extent, and this was certainly the case for the animals studied by Casady and Lehman (1967). In neither case did the authors report specific behaviors, so it is difficult to estimate the rates of potentially-dangerous responses in habituated animals. Bond et al. (1974) examined the responses of ponies to two sonic booms; in this case the previous experience of the animals was unknown. Thus, only the Hannover theses measured behavioral and physiological responses of naive cattle and horses (Beyer, 1983; Heicks, 1985; Heuweiser, 1982; Krüger, 1982; and Erath, 1984) to very low-altitude aircraft overflights and hovering helicopters.

Table 17 summarizes the responses of all large livestock to overflights and sonic booms. Based on these data, very low-flying aircraft will stimulate running or thrashing in all or most large animals initially (100% of the 21 horses and 40 cattle in the Hannover studies thrashed or ran on initial exposure). Note that the stimuli in these cases are among the most intense that can be produced by an aircraft - helicopters and high-speed jets flying less than 50 m from the animals.

Fewer than 1% of 1193 habituated horses and 10,000 cattle in Casady and Lehman's study responded in this fashion, if we presume that all the "abnormal" behavior they reported was of this sort (in fact, the rate is probably lower). Espmark et al. (1974) reported rates of 50% "high" levels of activity in cattle and 5% of sheep, but this definition included standing up (in prone animals), and none of the animals suffered any injury and none ran more than 20 m. The cattle in this study

became less responsive with repeated exposure, so they obviously were not fully habituated to the stimulus.

None of these authors measured habituation directly, including the Hannover students. The latter used changes in heart rate as an index of habituation. Unfortunately, they did not report changes in behavior with repeated exposure, except anecdotally, so it is difficult to correlate heart rate and behavior directly. Although heart rate does not allow us to predict whether an animal runs or damages itself, it does provide a direct measure of the degree to which the animal is startled. In this case it is the best available measure of habituation.

Based on this rationale, we suggest that 100% of large animals are initially extremely startled by very low-level overflights and loud sonic booms, and that their responses to these sounds decline with repeated exposure to a minimum of around 1% of animals. We can estimate the rate of these declines and the number of exposures required by measuring relative changes in heart rate.

We analyzed the heart rate data provided in the Hannover theses to make an estimate of the habituation function. The variables that affected the rate of decline in heart rate (as stated by the authors) were aircraft type, duration of the overflight, sequence of exposures, interval between overflights, sound level and onset-time. They also thought that breed and individual differences were important, but they do not present enough data to evaluate these variables.

We extracted heart rates and these variables as well as possible from the raw data in the theses. We did not analyze Heicks' data, as he stated clearly that his animals were often diseased and their heart rates did not vary with stimulus as expected, suggesting methodological flaws. We included only data on jet overflights, as the helicopters, especially while hovering, represented a very different visual and tactile stimulus, and were plainly much more arousing to the animals. We found only a very crude estimate of onset time, and we finally abandoned the attempt to analyze this variable, substituting total duration of the overflight as a crude estimate. Heart rates were quantified by measuring the peak value for heart rate simultaneous with each overflight, starting with the

beginning of a "run" of overflights (6-15 flights). These heart rates were then scaled against the peak value for heart rate, to obtain a proportional estimate of response (PHR).

We first examined the data graphically, to determine the relative importance of each co-variable. Figure 3 shows the mean, standard deviation and range for PHR for horses and cattle by aircraft type (jets only). The Starfighter 104g and Phantom F4 aircraft elicited the greatest heart-rate responses, although they were never the first aircraft in any sequence of experiments. Krüger (1982) considered them less effective than the Fiat G91, but he exposed his horses to the Fiat G91 first, so that most of his effect may have been the novelty of aircraft exposures. In combination with Erath's (1984) data, the Fiat is not as effective. The Starfighter and Phantom aircraft were also the fastest-flying and loudest, suggesting some contribution of sound level and onset time to the effect. The order of effect was the same for both cattle and horses (Starfighter, Phantom, Fiat; other aircraft were not used in all studies).

Conditions of the study (Figure 4) did not affect response in cattle, but did somewhat in the case of horses. The differences were not large (mean PHR .54 versus .69) but were detectable. Krüger's animals had higher mean PHR and somewhat lower variability. The reason for this difference is unknown.

Sequence (the number of the experiment) accounted for PHR well in the case of horses, but only poorly (Figure 5) in the case of cattle, whereas order (the number of the overflight in any given experiment) appeared to have a consistent effect (Figure 6). Heart rate declined with time during the experiment for all jet overflights, indicating that the animals were adapting to the experimental overflights.

We also measured interval, the time between successive overflights, whether within or between experiments. Interval alone was only a marginally significant determinant of PHR (regression analysis, $N=357$, $F=2.49$, $P=.11$), and explained almost none of the variability for cattle.

Sound level alone was similarly ineffective at explaining the variability in the data. Duration (a measure of onset time) was somewhat more effective, as it was a significant determinant of PHR (regression analysis, $F=16.02$, $P< .001$) for cattle. However, it explained only 4% of the variability in the data.

These results suggest that some of the variables were not independent of one another. We reanalyzed the data on PHR using a mixed regression model, holding duration, order, sequence, interval, sound level, study, and aircraft-type as factors. We found significant interactions between aircraft type and duration, aircraft type and sound level, aircraft-type and study, and interval and order (Table 18). The aircraft presentations were not balanced in any way in the Hannover studies, so this result is not unexpected.

In addition to these interaction effects, which are suggestive of deficiencies in the study design or the choice of factors, the greatest proportion we could explain of the variability in the data was 42% ($R^2 = .42$, $F=31.67$, $P < .001$ for horses), suggesting that a large proportion of the variability in the data could be explained by the identity of the animal and other unpredictable factors. Often the authors did not record the responses of each individual to more than one aircraft type, so it became impossible to tease out the effect of individual differences.

The most useful information may be summarized as follows:

1) Aircraft type (which includes all the acoustic as well as visual features of the aircraft), study (presumably representative of management conditions) and sequence were the most important predictors of response in the Hannover studies.

2) If we examine only the acoustic features of the overflights, order of the overflight in a sequence had more effect than sound level, although sound level had some effect. This ordering was true for both horses and cattle. Duration and interval between overflights were confounded with other

predictors, and could not be evaluated. We suspect that a good measure of onset time would be a better predictor, as it is for humans (Hoffman and Searle, 1968).

3) The data on sound level fell within a narrow range (90-120 dB) which was well above the threshold for strong behavioral responses (estimated at 85-90 dB based on Espmark et al. [1974]). Thus, the sound level data were not really stratified (deliberately; the authors were trying to provoke strong behavioral responses).

4) The heart rates declined with repeated exposure more or less as expected based on data in Espmark et al. (1974). The decline was similar to decline in responses reported by other studies of habituation in humans and laboratory animals (Hoffman and Searle, 1968; Peeke and Herz, 1973; Borg, 1978 a,b,c). The form of this function is roughly exponential.

5) The influence of individual variability on the results could not be determined from the data in the Hannover theses, although we estimate that it is a large proportion (the factors we did measure could only account for a little over 40% of the variability in heart rate values).

3.2.7.1.2 Habituation and dose-response relations measured in other studies. Espmark et al. (1974) reported habituation and dose-effect relations for onset time and sound pressure level of low-altitude overflights and sonic booms. They measured responses of sheep and cattle. Unfortunately, it is impossible to characterize the rates of dangerous behaviors (running, biting and so on) from their data because they used a relative scale of behavioral measurements that put standing up in the same category with running. Also, their animals were already somewhat familiar with aircraft overflights at the time of the experiments.

Nevertheless, the study is extremely useful. Figure 2b shows the dose-effect relation for rise time of the noise in cattle. They define the term somewhat loosely as "the time between onset of the boom and maximum overpressure" (pp. 108). Based on this measure, short rise times (.1 sec) are the most effective at arousing a startle response. Rise times of 3-4 seconds are least effective, and

the function is bowed, with responsiveness rising again to at least 62% (of animals) with rise times of 12 seconds and over. This suggests that the total duration of the stimulus also has an effect on response.

Figure 2c shows the relation between strong responses of cattle and sequence of sonic boom exposures. In this case, strong might mean any behavior from rising sharply to running, depending on the previous behavior of the animal. It is only useful as a relative measure. However, the form of the habituation function is similar to functions presented by Hoffman and Searle (1968) for humans and to the response function in Stermer et al. (1982) for sheep. Only a few of the animals reacted (50% or less), suggesting that sonic booms are either a less effective stimulus or the animals were better habituated (or both). Note that the form of the function declines rapidly within the first 10 exposures and declines to a minimum within 30 or so exposures.

Unfortunately, we cannot evaluate habituation to low-altitude overflights based on this study. The altitude decreased and sound level increased over the course of the 30 or so overflight experiments; thus, as animals became habituated, the stimulus became more intense, and the two effects tended to cancel. Aircraft type also varied somewhat. The end result was a variable and unpredictable relation between sequence of overflights and responses. We can only conclude that above a certain sound-level threshold (around 100-105 dB), even relatively experienced animals will exhibit some type of strong movement when exposed to low level overflights for the first time.

The analysis of the dose-response relation between sonic boom overpressure and animal activity was similarly confounded. Boom overpressures generally increased over the course of the experiments, and rise times varied unpredictably. Thus, the responses of cattle with overpressure cannot be interpreted.

Subsonic overflights at least did not have confusing changes in rise-time. Even though the animals were becoming increasingly habituated over the course of the experiments, strong responses increased with overpressure. There was a threshold of response somewhere around 90 dB.

Responses increased to a maximum above about 110 dB, affecting 40-50% of the animals (the most that responded with startles in this study).

The authors measured duration of the responses in sheep. Although reaction duration did not seem to vary systematically with overpressure (given that overpressure increased with experience), it did decline rapidly with repeated exposure. Sheep responded for an average of 40-45 seconds to the initial two sequences (10 booms). After that, response duration declined to around five seconds, indicating that the animals had habituated to the noise.

The authors also measured distance travelled during a response. Distance travelled did not vary with overpressure - animals moved on average 7-11 m, with none travelling more than 30 m. The "herds" of these animals were small (18 sheep and 20 cattle), and they were already somewhat accustomed to aircraft noise at the start of the study.

3.2.7.2 Description of damage in large domestic stock.

The analysis of the studies is only useful if we can relate the behavior of the animals to some significant effect. Unfortunately, the data on effects on large animals is very weak, largely because none of the controlled studies documented any serious effects.

The Hannover theses were the only studies of completely naive animals subjected to very strong aircraft exposures. The claims files suggest circumstances under which damages might actually be expected to arise, but cannot suggest rates, as they are a biased sample of the effect of exposures (farmers only complain when they experience a loss). They suggest that herd size plays a role in aggravating losses by allowing stampedes, and crowding, but the data in the claims does not support any herd size effect.

The data we have outlined above suggest a simple description of how damages might occur in large stock.

- The Hannover theses suggest that 100% of animals are motivated to respond if naive and if exposed to the most extreme stimuli. Espmark's study suggests that around 40-50% of animals that have had some experience with aircraft (but presumably not with intense low-level overflights) respond on initial exposure. Habituated animals do not respond unless the aircraft are very close (i.e. within 50 m).

- Animals do not run in a completely uncontrolled fashion, even if confined in a paddock. They do watch where they are going to some extent. Thus, damages are accidents which occur because footing is poor or the barricades around them are dangerous in some way (e.g. barbed wire). The Hannover theses made this suggestion explicitly (Beyer, 1983).

- Of the 40 cattle and 20 horses in the Hannover study, one cow shoved a head and foot through a fence and two jumped out of their enclosure. None were damaged. Half of the animals were confined and half free-ranging.

- The functions for habituation that we reported above show that animal responsiveness declines from maximum to minimum within 30 exposures, and that the greatest declines occur within the first 10 exposures. Unfortunately, we cannot estimate the exact proportions of animals running from the Hannover theses, just the relative rate of decline. We will presume that the function begins at 100% of animals and declines to 10%, the approximate proportion of animals in the Hannover theses that never became fully adapted to low-altitude overflights.

- Sound level, onset time, and duration of the stimulus also have an effect on the response. We can approximate the effect of sound level based on the Hannover theses and Espmark et al. (1974), and of some combined measure of onset time and duration.

Based on this picture, we can estimate the number of animals that will be lost in the event of a first exposure to a very low-level overflight and scale this number to account for previous exposure and sound characteristics. If we look only at the free-ranging animals in the Hannover studies (we will scale for confinement later, based on the heart rate data), the number of potentially damaging incidents is 1/50 animals and attempts at escape are 2/50 (2% and 4%, respectively). Since all the overflight sequences aroused some form of running, these damages occurred over 31 overflight incidents. The per animal-incident rate of damages is .32% (that is, if you expose 100 large animals to one incident, you run the risk of damaging .3 of those animals). The per animal-incident rate of escapes is .6%, based on the same logic.

While this rate may seem low based on the traumatic injuries reported in the claims, note that the proportion of animals affected are roughly correct (Table 8) if we do not take into account the number of incidents (which the claims files do not report accurately), and if we presume that every animal that collides with or jumps a barrier is at risk. The estimate based on the Hannover studies is actually a worst-case rate, as the animals were exposed to helicopters hovering over their enclosures, a far more effective stimulus than aircraft overflights. The rate may be modified by herd size (herd size will certainly increase the losses due to escapes).

In our scenario, animals exposed to lower levels of aircraft noise or higher overflights would run fewer risks. Habituated animals (those that have been exposed more than 30 times) run no risk. Note that we cannot account for individual, breed, or species differences in responses based on what little data we have.

3.2.7.3 Description of damages in domestic fowl.

We have no data that would allow us to calculate a habituation function for domestic fowl, although we must presume that the habituation function is similar in form (a decaying exponential), if not in its parameters, to that for domestic mammals. Brown and Glick (1971) provide a crude estimate based on heart-rate measurements, showing that rates decline to normal after repeated exposure to periodic sounds (four four second tones separated by a three minute interval) as well as continuous noise. However, their stimuli were poor models for aircraft noise, and they give no indication either of the habituation function or of the behavioral responses of the animals. The other studies of fowl response have provided no data that would allow estimate of any type of dose-response relation or habituation function.

Loss rates (numbers of birds found dead) can be estimated to some extent based both on data in the literature and on the best-documented of the claims. Table 19 summarizes these data. These loss rates seem to be more dependent on the number of animals held together than was the case

for livestock. This is sensible, as most domestic fowl are lost to crowding and piling, a flock effect, as opposed to individual collisions.

Like large mammals, birds respond with movement to sounds above a threshold, which we estimate to be 85-90 dB based on the observations of Thiessen et al. (1957), and Edwards et al (1979). The form of this function must remain speculative at this point, as no one has calculated any type of dose-response relation for domestic birds.

3.3 Summary of Expected Effects and Caveats

3.3.1 Rationale for Evaluating the Summary

The synthesis outlined above classifies effects into probable, possible, unlikely, and unknown based on the quality of the data in the literature. Even a cursory reading of this analysis shows that the literature provides only sketchy proofs for even the most obvious effects and does not cover more subtle effects at all. We have used it as an opportunity to determine which effects should be investigated further and which should be treated as improbable, rather than as a proof that the unlikely effects could never occur.

However, we wanted to be sure that our classification did not overlook information available to experts on animal disease. We solicited opinions on the classifications we developed from four animal health professionals (Appendix 2) with experience in a variety of pertinent disciplines, including epidemiology, toxicology, stress physiology, poultry science and large animal medicine. We wanted to make our evaluation as conservative as possible and also to put the problems created by aircraft noise into perspective with stresses from other sources. We also wanted to determine which domestic animals are most likely to be susceptible to damage from frights in general, based on the experience of professionals.

3.3.2 Description of the Summary

Appendix 3 represents the results of our review after two days of discussion with these experts. It lists the effects that have been documented to some extent in the literature and in clinical records, the ways that these effects could (or should) be measured, the type of study that would be required to document the effect, an evaluation of the likelihood of the effect (using our criteria), and the type of setting in which the effect could occur. Some of the effects in Table 18 were added for completeness (such as effect on parenting behavior in large stock). They are not listed above because they have never been studied. Unknown effects were evaluated based on clinical experience with other sorts of frightening stimuli, as a way to estimate what problems are worth pursuing.

The existing literature does not describe a number of factors that the experts felt might be important in predicting the effects of startles. The likelihood that an animal will panic and the consequences of that panic depend on a number of factors, the most important of which are:

1) Housing type, which would determine whether the animal saw the aircraft and whether it had the chance to damage itself when frightened.

2) Animal species or breed, which would determine whether the animal was temperamentally prone to respond.

3) Pre-stressing conditions, such as genetic or physiological conditions that would predispose the animal to suffer ill effect during a panic.

The appendix is divided into sections by major group of animals. Under each group, the appendix is sub-divided into two sections, one for typical members of the group, and another for animals that are particularly likely to be affected by a disturbance. Constraints imposed by housing conditions are listed with each potential effect. The evaluations in the table are based on the presumption that

on MTRs sorties may be flown over animals with little previous exposure to aircraft noise at low altitudes (500 m and below) for period of up to several months. It also presumes that exposures will not exceed 5-10 per day in any area, and that exposure to extremely low flights (below 100 m will be rare).

The major difference between the evaluation based on the literature and the summary in Appendix one lies in the estimates for effects on pre-stressed animals. This evaluation is difficult to apply to the EIAP because the planner will not know how many animals in any given area may be "pre-stressed", and is not accountable for this unpredictable condition. However, this table will be invaluable for understanding the conflicts between the claims and the published literature and for responding to the concerns of farmers who hold especially susceptible animals (e.g. pigs with Porcine Stress Syndrome).

3.4 Gaps Identified in the Literature and Recommendations for Future Research

We have discussed the many deficiencies in the literature at length in section 3.2. In making the following list of recommendations, we have eliminated those potential effects that have been examined and not substantiated (unlikely in our classification). This list does not pretend to include all the subtle effects or special circumstances that might arise - these are beyond the scope of the EIAP. Based on the literature, the greatest gaps exist in our understanding of the most probable and common effects precisely because the claim-oriented approach of most studies has been aimed at subtle effects. We do recommend ways of obtaining the type of background information necessary to design studies of subtle effects, such as induced abortions or reduced fertility.

1. The probability of injury due to startles is poorly-quantified in most domestic animals - Habituation is poorly quantified and we do not have good epidemiological information on the extent of the problem for any type of startle, let alone for the relatively rare startles induced by aircraft overflights. We know the form of the habituation function because studies have been done on other mammals (Fig. 7). We cannot conduct experiments to determine rates of casualties after overflights

due to the cost and the ethical problems associated with such studies. Based on the estimates we have gleaned from the literature, such experiments would involve hundreds of animals, especially since herd size is probably a factor in the probability of effect. At this point collecting clinical information on stampedes and startles would be much more useful than experiments.

2. Although the effect of sounds on physiological responses has been quantified to some extent, the relation between physiological responses and effects on the productivity of animals is poorly-quantified - This gap makes much of the existing data on "stress" induced by noise difficult to interpret. The dose-effect relation between rises in glucocorticosteroid and catecholamine levels and effects must be quantified before measurements of hormones or heart rates will tell us very much about effects on production. This type of research will be of long term, and is not necessarily within the scope of the NSBIT program. The most useful dose-effect relations to develop would be the relation between rises in adrenal hormone levels and milk production, and the relation between startles and changes in the hormones that control gestation in mammals, since the physiology of both is relatively well-understood. Previous research indicates that the relations will be complex (e.g. the Hannover theses and Lefcourt et al., 1986), so this research will not help the EIAP directly for some time.

3. We know almost nothing about the physiological effects of noise on birds. Although there is some literature that defines such effects on most mammals, we know almost nothing about the physiological responses of birds (exceptions are Wildenhahn et al., 1976a, and Brown and Glick, 1971). Glucocorticosteroid levels are commonly used as a measure of stress in mammals, but the corresponding hormone for birds is not known. Again, much basic research will be needed before physiological responses to noise can be related to effects on production.

4. The definition of "effect" will probably change in the next 10 years to include consideration of animal well-being. This topic is poorly understood at present. In our analysis and in the description of the model, we are suggest that the most important criteria for determining "effects" are degree of injury caused and the extent to which animal production is altered, under the

presumption that an animal that produces normally is not affected, regardless of its behavioral responses. Our perspective is narrow because the concern of NSBIT is to develop better ways of assessing the environmental impact of aircraft activities. At present, the EIAP defines impact in terms of injury and productivity.

This narrow definition does not consider a type of effect that is receiving increasing political and social concern, the well-being of animals. This effect would be on what we might call the "psychological" health of the animal and its comfort (it is commonly considered in the case of humans). At present, the EIAP does not consider whether animals find being scared by an aircraft unpleasant and what degree of unpleasant feelings are acceptable. Politicians and animal rights activists are beginning to ask questions about effects on well-being, so it may become part of what an environmental planner must consider in the future. At present there are too many basic questions about how we would even define well-being, let alone measure it, for NSBIT to conduct research on the topic, but the supporting documentation in ASAN should include information on well-being.

4.0 DESCRIPTION OF THE DOSE-RESPONSE MODEL FOR EFFECTS OF AIRCRAFT OVERFLIGHTS ON DOMESTIC ANIMALS

4.1 Rationale

The based on our analysis (section 3), domestic animals fall into three major groups for the purpose of modeling the effects of aircraft noise. These are: large stock (horses, cattle, sheep, goats, and exotic stock), domestic poultry (turkeys, chickens and ducks), and a mixed group that includes swine and fur bearing animals. These animals are grouped by the effects that aircraft noise can have on them and the types of production that can be affected, based on the data in the claims files and in reports of studies.

There is no information that would allow us to detect niceties such as differences in responsiveness by breed or species within these groups. The general outline of the model we propose for each group will apply to all the species in the group. Differences in breed or species will be accommodated by differences in the input taken by the model, probably as data become available. As a result, the variability in the estimates that the model produces initially will be high.

The groups are characterized as follows:

1. Large stock - The most serious damages to large stock are due to panic running or aggression (collisions, tramplings, biting, kicking) in which animals escape or are damaged. These are mainly caused by low-level overflights, as stock appear to be relatively insensitive to sonic booms. Other, lesser effects, especially for pre-stressed animals, involve loss of productivity, i.e. reduced milk production, weight loss, and abnormal terminations of pregnancy. These lesser effects are unproven at present and will not be modeled. However, the model will be designed to accommodate dose-effect relations for these losses of productivity if data become available in the future.

2. Poultry - The most serious damages to poultry are due to accidents and suffocations when the birds crowd or pile in a panic. Poultry may fly or attempt to fly, and may suffer damage as a result. Crowding and piling are equally induced by sonic booms and overflights. Other effects are productivity-related, specifically, reduced laying capacity, fertility or weight gain. Poultry are housed in flocks ranging from small groups (4 hens in a battery cage) to large (several hundred poults in a pen), so group size is likely to be a factor in determining damages.

3. Fur bearers and swine - Although these two groups are biologically dissimilar, they share some common characteristics that are important to determining the effects of noise. They produce large litters of relatively small young, they are carnivorous (pigs will kill and eat small animals), and they are generally managed in confined settings (individual animals rather than groups in a small area). We cannot at present model any effects on these animals because the weight of the existing data indicate that the most important effects claimed for these species (mothers killing their offspring after a startle, abnormal terminations of pregnancy) have never been properly documented. Although we have collected the same types of information on these species as for the other groups, we do not have enough data on any effect to make predictions about losses. The machinery to create a model for the effects of aircraft activity on this group will be provided in ASAN, but no model will be implemented.

In basic outline, the models will each have two parts, only one of which can be implemented at present.

1. The first part will model the possibility of traumatic losses due to particular overflights; each overflight will have some potential for startling individuals, herds or flocks into panic flight, and each flight will have some potential for causing damage.

2. The second part will model possible losses in production, and will be based on cumulative exposure to overflights, with the relative contribution of each overflight determined by animal

naivete and features that describe the nature of the overflight, ie. sound level, onset time, and (possibly) approach distance.

Losses in the first case will be reported as numbers of animals that escape or are damaged. Losses in the second will be reported as proportional declines in productivity (i.e. 3% loss, etc.). At present the productivity-related portion of the model makes no claims about the mechanism of damage from a physiological point of view. Although such models have been proposed (Dufour, 1980), there is no way at present to relate particular dosages of noise to particular levels of effect - the physiological responses to noise have been documented to some extent, but the relation between physiological responses (such as a rise in catecholamine or glucocorticosteroid levels) and effects (if any) is poorly understood. However, the model will be designed in a modular way, so that if our understanding improves in the future, the model can be altered to include relations between noise, physiological effects, and effects on the productivity and well-being of animals.

4.2 Limitations of the Models

By the standards of modern, physiologically-based models for the effects of stressors (e.g. models described, Dufour, 1980; Moberg, 1985) this model is simple. It is intended to be simple. It starts with the premise that a complex model for effects cannot be developed until we have established that there is any effect at all and until we understand how the effect is produced to some extent. These models will be most useful for predicting traumatic effects of aircraft-induced startles on animals, the most important cause of damages.

By making the model simple and by concentrating on traumatic damage, we may be seen as denying the possibility that other effects on productivity or physiology can occur. We are not. We are suggesting that these effects are so subtle that they cannot be measured by conventional experimental techniques (the sort that have been used so far), and that traumatic damage is a far more important source of loss.

4.3 Descriptions of the Models

Figure 8 shows the design of the model for effects of aircraft overflights on all domestic animals. It is broken down into subsections by animal group. Most of the model will not be implemented at this time due to lack of information. Two subsections, the one on large stock and poultry will be implemented.

4.3.1 Description of Model for Large Stock

Figure 9 shows a schematic of the model for large domestic animals, indicating how the model would arrive at its estimates. It is broken into two segments, one on effects that may be induced by single overflights, and one on effects that (if they occur) require multiple exposures.

4.3.1.1 Modeling the probability of escapes or damages due to trauma.

1 This portion of the model takes as input the locations of farms, the type of stock on the farm and their numbers, and the type of operation. These data must be obtained from local management agencies. The zone of influence of a low-flying aircraft is 1200 m on either side; outside this range, aircraft are unlikely to arouse dangerous behavioral responses. This limits the number of farms under the flight path that the planner must identify. We have chosen this limit somewhat arbitrarily, as an aid to the planner. In fact, the effective zone of influence will be determined by the sound level of the aircraft.

2 The number and type of sorties that pass over the farm and the maximum sound level of each will be determined by ASAN, which then generates a list of overflights. Habituation to the overflights will be determined by the exposure to each type of sortie independently, although habituation probably is not independent in practice. This simplification makes the model more conservative, and it reflects the strong effect of aircraft type on response that we observed in the Hannover studies.

3 The model must presume that animals are naive when the MTR is opened for the first time. Separations between sorties of longer than a specified interval will "reset" the animals to the naive condition. The interval will be defined for each type of stock in a table in ASAN. Initially, the value will be given as one year arbitrarily.

4 The model will estimate the number of animals that run. Based on Figure 2c, there is a response threshold at around 85-90 dB. This threshold may later prove to vary somewhat based on the onset time of the sound and the approach distance; for now we cannot predict the effect of these factors. Below this threshold, only a small percentage of animals respond. Above it most or all respond. The function takes the form of a decaying exponential,

$$e^{(x-a)/b}$$

where P is the proportion of animals running, x is L_{max} (the maximum sound level of the overflight), a=115, and b=36. This equation is valid for $0 \leq L_{max} \leq 115$. If $L_{max} > 115$, P=1.0

5 This proportion will be scaled by breed, herd size, and management conditions. At present, breed and herd size scale by 1.0, as the existing data do not allow predictions based on herd size. Scaling by management type is listed in a table in ASAN. For example, small ranches scale by 1.0 as they are likely to have barbed wire fences or other potentially-damaging housing conditions, whereas larger and better-constructed commercial operations with 1000 or more head of stock scale by 0.5. The scaling factor will have to be determined somewhat arbitrarily at present, but it will be based on the anecdotal information in the claims (which provide useful worst-case estimates).

6 The resulting proportion will also be scaled by habituation. The form of the habituation function is given in Figure 10 (taken from Peeke and Herz, 1973).

7 The resulting proportion will be multiplied by the number of animals on the farm to determine the number of animals responding. This number will be incremented after each event. The total will be the number of animal-incidents. The number of animal incidents will be multiplied by .001

to obtain the number of injuries or deaths anticipated, and by .002 to determine the number of animals that will escape.

8 The model will report the per-capita rate of casualties (injuries or losses) and escapes. Abortions due to trauma eventually will be listed with casualties.

4.3.1.2 Modeling the probability of production losses.

This portion of the model will not be implemented at this time because we have no way of predicting the relation between exposures and loss of productivity for any of the effects that have been suspected. Experiments underway now may provide this kind of information in the near future.

1 The input listed in Part 1 will be similar for this part, including the distance and acoustic characteristics of the overflight.

2 Instead of determining the effect sortie by sortie, this part of the model will look at cumulative overflight effects only. The cumulative exposure will be determined by calculating the effect of the maximum sound level of the sortie (or approach distance or onset time, as we learn the effect of these factors). If the effect is over the threshold of 85-90 dB it will receive a value of 1 and otherwise a 0. The effect will be scaled by the habituation function and animal type (this is where information on pre-stressed animals or different breeds can be included). The outcome will be a measure of cumulative exposure.

3 The model will measure the effect by calculating the relation between cumulative exposure and proportional effect on productivity. For example, in the Hannover studies cumulative effects of around 100 (in units of scaled flights) resulted in a hypothetical maximum abortion rate for dairy cattle of around 10% (excluding losses due to disease). This rate is probably not believable because

the diseased herds should be eliminated from the analysis entirely, but it illustrates how the estimates could be made.

4 The model would report the expected proportional effect. The planner would determine the variability around this estimate by referring to a table generated during the sensitivity analysis.

4.3.2 Description of Model for Poultry

Figure 12 shows the design of the model for effects of aircraft overflights on poultry in a schematic form, indicating how the model would arrive at its estimates. It is broken into two segments, one on effects that may be induced by single overflights, and one on effects that (if they occur) require multiple exposures.

The description is as follows:

4.3.2.1 Modeling the probability of damages due to piling and crowding.

1 This portion of the model takes as input the locations of farms, the type of poultry on the farm and their numbers, and the type of operation. These data must be obtained from local management agencies. The zone of influence of a low-flying aircraft is 1200 m on either side of the aircraft, as before.

2 The number and type of sorties that pass over the farm and the maximum sound level of each will be determined by ASAN, which then generates a list of overflights. Habituation to the overflights will be determined by the exposure to each type of sortie independently.

3 The model must presume that the fowl are naive when the MTR is opened. Separations between sorties of longer than a species-specific interval will "reset" the birds to the naive condition. Initially, the interval will be defined as 12 weeks for broiler chickens and 24 weeks for meat turkeys (normal

time to market age). The interval has yet to be determined for laying hens, which live somewhat longer.

4 The model will estimate the number of birds that crowd from the relation in Figure 7. This relation was chosen rather arbitrarily based on data from other species, and its threshold is set to around 85 dB, the threshold for strong responses in the domestic duck (Thiessen et al., 1957); it will be modified later based on experiments now underway, to account for the onset time of the overflight. Since most poultry are now raised under cover, approach distance will not be a factor. The relation has the form

$$e^{(x-a)/b}$$

where $a=101$, $b=22$, $x=L_{max}$. The relation is valid between $0 \leq L_{max} \leq 101$.

5 This proportion will be scaled by flock size and management conditions. We estimate the relation between flock size and effect using data in Table 19. The scaling factor for management type will be listed in a table in ASAN; it will be set to 1 for the time being for lack of data.

6 The resulting proportion will also be scaled by habituation. The form of the habituation function is given in Figure 10 (taken from Peeke and Herz, 1973).

7 The final proportion will be multiplied by the number of birds on the farm to determine the number of birds responding. This number will be incremented after each event. The total will be the number of bird-incidents. The number of will be multiplied by .0001 to obtain the number of injuries or deaths anticipated.

8 The model will report the per-capita rate of casualties (injuries or losses).

4.3.2.2 Modeling the probability of production losses.

This portion of the model will not be implemented at this time because we have no way of predicting the relation between exposures and loss of productivity for any of the effects that have been suspected (weight loss in meat poultry, reduced fertility or decreased egg production). Experiments underway now may provide this kind of information in the near future.

1 Include the input listed in part 1.

2 Instead of determining the effect sortie by sortie, this part of the model will look at cumulative overflight effects only. The cumulative exposure will be determined by calculating the effect of the maximum sound level of the sortie (or approach distance or onset time, as we learn the effect of these factors). If the effect is over the threshold of 80-85 dB, it will receive a value of 1 and otherwise a 0. The effect will be scaled by the habituation function and poultry type (this is where information on pre-stressed birds or different breeds can be included eventually). The outcome will be a measure of cumulative exposure.

3 The model will measure the effect by calculating the relation between cumulative exposure and proportional effect on productivity.

4 The model would report the expected proportional effect. The planner would determine the variability around this estimate by referring to a table generated during the sensitivity analysis.

4.4 Sensitivity Analysis

During the next phase of this project, we will conduct a sensitivity analysis that measures the importance of the various input parameters in determining the outcome of the model. This sensitivity analysis will consist of a series of Monte-Carlo simulations. The outcome will be quantitative data on which parameters are most important (hence which should be measured most

carefully in the future studies) and a table showing estimates of the error around the effect returned by the model for each species. These errors will be reported along with the estimate of effect when the environmental planner submits an EIS or FONSI.

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Note: The number given at the beginning of each reference is its CITASAN (ASAN citation database) identification code. References without numbers have not been entered into CITASAN as yet.

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APPENDIX 1

SUMMARY OF THE INFORMATION FROM THE USAF CLAIMS FILES THAT WAS ENTERED INTO A DATABASE AND ANALYZED

APPENDIX 1.

The database consists of three interconnected panels: 1) CLAIMS, 2) ANIMALS, and 3) INCIDENT.

CLAIMS

Claim number	The number assigned by Air Force personnel organizing the claims files. It consists of the year the claim was received and the claim number for that year (i.e. 60-01 was the first claim received in 1960).
Date of claim	The date the claim was presented to the Air Force. When the exact date was not available, the date was approximated and a note was made in the "Note" field.
Claimant	This usually includes the last name of the individual making the claim, although occassionally the name of the farm or organization was the only name available.
Claimee	The Air Force Base against which the claim was made.
City, State	The location there the incident occurred.
Examining veterinarian	Originally included in case more information was needed about a particular claim, but this field is not very useful as there is no information about how to contact the individual, so it is rarely used.
Type of incident	Includes sonic boom, low-level overflight, crash, ground traffic, aircraft landing, or poisoning.
Amount of original claim and Amount approved	Self-explanatory. If amount approved was unknown, $0.00 was entered and a note was made in the "Notes" field. It was also noted if the claim was disapproved.
Litigation	Indicates if the claimant actually filed suit against the Air Force.
Interested Govt. official	Any member of the federal, state, or city government who may have become interested in the case and could have affected its outcome.
Notes	Special information about the case that was not made clear in the other fields. Whether the claim was disapproved and reasons for disapproval are indicated here. Connections or references to other claims are described. If a substantial portion of the claim is for personal injury or property damage not related to animal impact (for example, structural damage caused by the pressure wave of a sonic boom), it is described here.

ANIMALS

Claim number	Carried through from the CLAIMS panel when information is entered.
Index number	Assigned to the record by the database, and has no relation to the record itself.

Common name — Along with taxonomic information, this is entered separately for each species of animal on the claim, one species per record.

Type of injury — Injury suffered by the animal itself only; any damage to people or property is described in the "Notes" section of the CLAIMS panel. Types of injury include smothering due to crowding, death due to trauma, trauma due to panic, killing/eating young, abortion, weight loss, reduced production (referring to eggs, meat, fur, piglets, milk, wool, foals, or fish), reduced fertility, abandonment of young, hatchability, debris injestion, disappearance (for example, when cattle break out of a pen and are unable to be found), animal quality (for example, if a mink is so upset that it can no longer be used as a breeder), pelt quality, poisoning.

Number of animals at farm — Self explanatory. This number is rarely reported.

Number of animals affected — Total number of the given species that was affected; may be a total of a number of different types of injuries to different animals. In the case of fur bearers destroying young, the number of animals affected only includes adults that destroyed or damaged young; the number of young affected is listed in the "Notes" field.

Notes — Explains injuries further if necessary, and lists the number of animals sustaining each type of injury if more than one type is reported.

<u>INCIDENT</u>

Claim Number and Index Number — See previous paragraph.

Type of aircraft — Model number, if reported, of the aircraft allegedly causing the damage.

Date of first incident and Date of last incident — Both listed if a series of incidents occurred, as was often the case.

Time of first incident — Self explanatory.

Altitude — The altitude of the aircraft at the time the damage occurred.

Distance from animal — The distance from the aircraft to the animal; rarely reported. Often the aircraft was "directly overhead", in which case altidude would also equal distance from animal.

APPENDIX 2

SHORT SUMMARIES OF THE CLAIMS AGAINST THE USAF FOR DAMAGE TO DOMESTIC AND WILD ANIMALS

The summaries include the species affected, what type of damage was done, how many were exposed and affected (if known) and how much was paid out on the claim. When the claim was not paid the amount is listed as "0.00". When data were not given in the claim, they were entered as blanks.

Appendix 2. Reported damages and award amounts for U.S. Air Force claims, 1955-1988. Note: The number of animals exposed and/or affected was often unknown. A $0.00 entry for Amount awarded could indicate either that no amount was awarded, or that the amount awarded was unknown.

55-01. Animal Type: deer.
Injury: disappearance.
Number exposed/affected: / . Amount awarded: $0.00.

56-02. Animal Type: mink.
Injury: reduced production (fur), killing/eating young.
Number exposed/affected: / . Amount awarded: $2,850.00.

58-01. Animal Type: horse.
Injury: trauma due to panic, disappearance.
Number exposed/affected: 40 / . Amount awarded: $0.00.

59-01. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: / 5. Amount awarded: $983.13.

59-02. Animal Type: cattle (dairy).
Injury: debris injestion.
Number exposed/affected: / 1. Amount awarded: $225.00.

59-03. Animal Type: mink.
Injury: killing/eating young, reduced production (fur), reabsorption.
Number exposed/affected: / . Amount awarded: $0.00.

59-05. Animal Type: chicken.
Injury: reduced production (eggs).
Number exposed/affected: 3783 / . Amount awarded: $0.00.

59-06. Animal Type: chicken.
Injury: death due to trauma, reduced production (eggs).
Number exposed/affected: 12000 / 2400. Amount awarded: $0.00.

59-09. Animal Type: mink.
Injury: reduced production (fur), killing/eating young.
Number exposed/affected: / . Amount awarded: $0.00.

60-01. Animal Type: turkey.
Injury: smothering due to crowding, weight loss.
Number exposed/affected: 2295 / 2295. Amount awarded: $3,864.00.

60-02. Animal Type: chicken.
Injury: death due to trauma, reduced production (eggs).
Number exposed/affected: / . Amount awarded: $0.00.

60-03. Animal Type: cattle (dairy).

Injury: trauma, death due to panic, abortion, reduced production (milk.
Number exposed/affected: 64 / 64. Amount awarded: $0.00.

60-04. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: 1 / 1. Amount awarded: $0.00.

60-05. Animal Type: geese.
Injury: reduced production (goslings).
Number exposed/affected: / . Amount awarded: $0.00.

60-06. Animal Type: turkey.
Injury: smothering due to crowding.
Number exposed/affected: / 140. Amount awarded: $134.71.

60-07. Animal Type: horse.
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $0.00.

60-08. Animal Type: cattle.
Injury: weight loss.
Number exposed/affected: 47 / 47. Amount awarded: $0.00.

60-09. Animal Type: chicken.
Injury: death due to trauma, reduced production (eggs).
Number exposed/affected: 802 / . Amount awarded: $0.00.

61-01. Animal Type: turkey.
Injury: reduced production (eggs), reduced fertility.
Number exposed/affected: / . Amount awarded: $0.00.

61-02. Animal Type: fish.
Injury: death due to trauma.
Number exposed/affected: / . Amount awarded: $0.00.

61-05. Animal Type: mink.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $0.00.

61-06. Animal Type: mink.
Injury: killing/eating young, reduced production (fur), animal quality.
Number exposed/affected: / . Amount awarded: $9,800.00.

61-07. Animal Type: bird (mynah).
Injury: death due to trauma.
Number exposed/affected: 1 / 1. Amount awarded: $0.00.

61-08. Animal Type: sheep.
Injury: death due to trauma.
Number exposed/affected: / 2. Amount awarded: $0.00.

61-09. Animal Type: horse.
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $270.00.

61-10. Animal Type: dog.
Injury: death due to trauma.
Number exposed/affected: 1 / 1. Amount awarded: $0.00.

61-12. Animal Type: chicken.
Injury: smothering due to crowding.
Number exposed/affected: / 4905. Amount awarded: $0.00.

61-14. Animal Type: chicken.
Injury: smothering due to crowding.
Number exposed/affected: 4500 / 64. Amount awarded: $33.60.

61-16. Animal Type: turkey.
Injury: smothering due to crowding.
Number exposed/affected: 2500 / 118. Amount awarded: $220.66.

62-01. Animal Type: poultry (waterfowl).
Injury: hatchability.
Number exposed/affected: / . Amount awarded: $0.00.

62-02. Animal Type: cattle.
Injury: death due to trauma, trauma due to panic.
Number exposed/affected: / 2. Amount awarded: $135.00.

62-03. Animal Type: rabbit.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $75.66.

62-04. Animal Type: pheasant.
Injury: hatchability.
Number exposed/affected: / . Amount awarded: $0.00.

62-05. Animal Type: cattle.
Injury: debris injestion.
Number exposed/affected: / 1. Amount awarded: $1,000.00.

62-07. Animal Type: horse.
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $1,048.00.

62-08. Animal Type: horse.
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $0.00.

62-09. Animal Type: horse.
Injury: death due to trauma.
Number exposed/affected: 3 / 1. Amount awarded: $175.00.

62-10. Animal Type: dog.
Injury: death due to trauma.
Number exposed/affected: 1 / 1. Amount awarded: $0.00.

62-11. Animal Type: chicken.
Injury: reduced production (eggs).
Number exposed/affected: / . Amount awarded: $242.65.

62-12. Animal Type: chicken.
Injury: smothering due to crowding.
Number exposed/affected: / 40. Amount awarded: $50.00.

62-13. Animal Type: cattle (dairy).
Injury: trauma due to panic, death due to trauma.
Number exposed/affected: 62 / 3. Amount awarded: $1,000.00.

62-14. Animal Type: turkey.
Injury: smothering due to crowding.
Number exposed/affected: / 356. Amount awarded: $587.22.

62-16. Animal Type: chicken.
Injury: reduced production (eggs).
Number exposed/affected: 1995 / 1995. Amount awarded: $1,521.00.

62-17. Animal Type: turkey.
Injury: smothering due to crowding, trauma due to panic.
Number exposed/affected: / 10529. Amount awarded: $1,587.00.

62-18. Animal Type: chicken.
Injury: smothering due to crowding.
Number exposed/affected: / 1650. Amount awarded: $990.00.

62-19. Animal Type: chicken.
Injury: smothering due to crowding.
Number exposed/affected: 10700 / 959. Amount awarded: $334.78.

62-20. Animal Type: chicken.
Injury: unknown.
Number exposed/affected: / 93. Amount awarded: $55.80.

62-21. Animal Type: horse.
Injury: death due to trauma.
Number exposed/affected: 1 / 1. Amount awarded: $379.00.

63-01. Animal Type: turkey.
Injury: smothering due to crowding, death due to trauma.
Number exposed/affected: / 424. Amount awarded: $578.28.

63-02. Animal Type: mink.
Injury: killing/eating kits, death due to trauma.
Number exposed/affected: / . Amount awarded: $0.00.

63-03. Animal Type: horse.
Injury: abortion.
Number exposed/affected: / 1. Amount awarded: $250.00.

63-04. Animal Type: turkey.
Injury: trauma due to panic.
Number exposed/affected: / 6711. Amount awarded: $0.00.

63-05. Animal Type: chicken.
Injury: smothering due to crowding.
Number exposed/affected: 1100 / 400. Amount awarded: $0.00.

63-06. Animal Type: chicken.
Injury: smothering due to crowding.
Number exposed/affected: / 276. Amount awarded: $200.60.

63-08. Animal Type: horse.
Injury: trauma due to panic, death.
Number exposed/affected: 2 / 2. Amount awarded: $436.00.

63-10. Animal Type: chicken.
Injury: smothering due to crowding.
Number exposed/affected: 4000 / 250. Amount awarded: $0.00.

63-11. Animal Type: cattle (dairy).
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $156.00.

63-12. Animal Type: cattle.
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $143.00.

63-13. Animal Type: chicken.
Injury: reduced production (eggs).
Number exposed/affected: / . Amount awarded: $0.00.

63-14. Animal Type: turkey.
Injury: smothering due to crowding.
Number exposed/affected: / 353. Amount awarded: $416.54.

64-02. Animal Type: mink.
Injury: killing/eating young, reduced production (fur), absorption.
Number exposed/affected: 98 / 98. Amount awarded: $831.47.

64-04. Animal Type: turkey.
Injury: trauma due to panic, smothering due to crowding.
Number exposed/affected: / 1745. Amount awarded: $3,283.80.

64-05a. Animal Type: chicken.
Injury: reduced production.
Number exposed/affected: 4100 / 4100. Amount awarded: $0.00.

64-05b. Animal Type: chicken.
Injury: reduced production, death due to trauma.
Number exposed/affected: 5913 / 5913. Amount awarded: $0.00.

64-06. Animal Type: pheasant.
Injury: loss of productivity.
Number exposed/affected: / 500. Amount awarded: $0.00.

64-08. Animal Type: turkey.
Injury: death due to trauma, weight loss.
Number exposed/affected: 20600 / 20600. Amount awarded: $13,879.50.

64-09. Animal Type: mink.
Injury: abortion, killing/eating young, death due to trauma.
Number exposed/affected: / . Amount awarded: $1,844.26.

64-10. Animal Type: chicken.
Injury: smothering due to crowding, reduced production (eggs).
Number exposed/affected: / . Amount awarded: $0.00.

65-02. Animal Type: chinchilla.
Injury: trauma due to panic, reduced production.
Number exposed/affected: / 43. Amount awarded: $0.00.

65-03. Animal Type: fish.
Injury: death due to trauma.
Number exposed/affected: / . Amount awarded: $0.00.

65-04. Animal Type: mink.
Injury: killing/eating young, trauma due to panic.
Number exposed/affected: / 43. Amount awarded: $1,936.00.

65-05. Animal Type: mink.
Injury: killing/eating young, trauma due to panic.
Number exposed/affected: 400 / 100. Amount awarded: $8,508.42.

65-06. Animal Type: mink.
Injury: killing/eating young, death due to trauma due to panic.
Number exposed/affected: / 7. Amount awarded: $864.34.

65-07. Animal Type: cattle.
Injury: trauma due to panic.
Number exposed/affected: 76 / 76. Amount awarded: $1,309.07.

65-08. Animal Type: mink.
Injury: killing/eating young, trauma due to panic, reduced production.
Number exposed/affected: / . Amount awarded: $0.00.

65-09. Animal Type: dog.
Injury: abortion.
Number exposed/affected: 1 / 1. Amount awarded: $0.00.

65-10. Animal Type: bird (canary).
Injury: hatchability.
Number exposed/affected: / 2. Amount awarded: $0.00.

65-11. Animal Type: mink.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $2,342.78.

65-12. Animal Type: turkey.
Injury: hatchability.
Number exposed/affected: / . Amount awarded: $0.00.

66-02. Animal Type: cattle (dairy).
Injury: abortion, reduced production (milk).
Number exposed/affected: / . Amount awarded: $0.00.

66-03. Animal Type: turkey.
Injury: weight loss.
Number exposed/affected: / . Amount awarded: $0.00.

66-04. Animal Type: chicken.
Injury: trauma due to panic, smothering due to crowding.
Number exposed/affected: / . Amount awarded: $0.00.

66-05. Animal Type: mink.
Injury: abandoning young.
Number exposed/affected: / 50. Amount awarded: $0.00.

66-06. Animal Type: mink.
Injury: killing/eating young.
Number exposed/affected: / 180. Amount awarded: $0.00.

66-07. Animal Type: mink.
Injury: killing/eating young, trauma due to panic, reduced production.
Number exposed/affected: / 167. Amount awarded: $627.89.

66-08. Animal Type: mink.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $2,129.74.

66-09. Animal Type: pheasant.
Injury: reduced production (eggs), hatchability.
Number exposed/affected: / . Amount awarded: $4,650.00.

66-09. Animal Type: quail.
Injury: reduced production (eggs), hatchability.
Number exposed/affected: / . Amount awarded: $4,650.00.

66-09. Animal Type: partridge.
Injury: reduced production (eggs), hatchability.
Number exposed/affected: / . Amount awarded: $4,650.00.

66-10. Animal Type: mink.
Injury: killing/eating young, reduced production.
Number exposed/affected: / . Amount awarded: $1,911.77.

66-11. Animal Type: mink.
Injury: trauma due to panic, reduced production (fur).
Number exposed/affected: / . Amount awarded: $0.00.

66-12. Animal Type: mink.
Injury: killing/eating young, reduced production (fur).
Number exposed/affected: 650 / 210. Amount awarded: $9,037.59.

66-13. Animal Type: cattle.
Injury: trauma due to panic.
Number exposed/affected: / . Amount awarded: $0.00.

66-14. Animal Type: chicken.
Injury: trauma due to panic, reduced production (eggs).
Number exposed/affected: / . Amount awarded: $0.00.

66-15. Animal Type: turkey.
Injury: smothering due to crowding, trauma due to panic.
Number exposed/affected: / 5603. Amount awarded: $10,043.20.

66-16. Animal Type: horse.
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $0.00.

67-01. Animal Type: poultry.
Injury: reduced production (eggs).
Number exposed/affected: / . Amount awarded: $0.00.

67-02. Animal Type: pheasant.
Injury: reduced production.
Number exposed/affected: / . Amount awarded: $0.00.

67-03. Animal Type: chicken.
Injury: reduced production (eggs), trauma due to panic.
Number exposed/affected: 4500 / 3000. Amount awarded: $0.00.

67-04. Animal Type: chicken.
Injury: reduced production (eggs).
Number exposed/affected: / . Amount awarded: $0.00.

67-05. Animal Type: cattle.
Injury: death due to trauma, weight loss.
Number exposed/affected: 72 / 72. Amount awarded: $0.00.

67-06. Animal Type: cattle.
Injury: abortion.
Number exposed/affected: / . Amount awarded: $0.00.

67-07. Animal Type: chicken.
Injury: reduced production (eggs).
Number exposed/affected: / . Amount awarded: $0.00.

68-01. Animal Type: mink.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $0.00.

68-02. Animal Type: mink.
Injury: killing/eating young, abortion.
Number exposed/affected: / . Amount awarded: $0.00.

68-03. Animal Type: mink.
Injury: abortion, killing/eating young.
Number exposed/affected: 1905 / . Amount awarded: $0.00.

68-04. Animal Type: chickens.
Injury: reduced production (eggs).
Number exposed/affected: / . Amount awarded: $0.00.

68-05. Animal Type: mink.
Injury: killing/eating young, reduced growth, reduced production.
Number exposed/affected: / . Amount awarded: $0.00.

68-06. Animal Type: chicken.
Injury: smothering due to crowding, trauma due to panic.
Number exposed/affected: 21000 / 1126. Amount awarded: $0.00.

68-07. Animal Type: cattle.
Injury: weight loss.
Number exposed/affected: / . Amount awarded: $0.00.

68-08. Animal Type: turkey.
Injury: reduced production (eggs).
Number exposed/affected: 2050 / 2050. Amount awarded: $0.00.

68-09. Animal Type: fish.
Injury: reduced production (eggs), killing/eating young (eggs).
Number exposed/affected: 570 / 570. Amount awarded: $0.00.

68-10. Animal Type: mink.
Injury: killing/eating young, trauma, abortion, abandonmemt of young.
Number exposed/affected: / . Amount awarded: $31,203.00.

68-11. Animal Type: mink.
Injury: unknown.
Number exposed/affected: / . Amount awarded: $0.00.

68-12. Animal Type: chicken (?).
Injury: reduced production (eggs).
Number exposed/affected: / . Amount awarded: $0.00.

68-13. Animal Type: chicken.
Injury: unknown.
Number exposed/affected: / . Amount awarded: $0.00.

68-14. Animal Type: mink.
Injury: unknown.
Number exposed/affected: / . Amount awarded: $0.00.

69-01. Animal Type: mink.
Injury: abortion, killing/eating young.
Number exposed/affected: / . Amount awarded: $0.00.

69-02. Animal Type: turkey.
Injury: smothering due to crowding, trauma due to panic.
Number exposed/affected: / . Amount awarded: $0.00.

69-03. Animal Type: chinchilla.
Injury: trauma due to panic, killing/eating young, abortion, loss of productivity.
Number exposed/affected: / 4. Amount awarded: $0.00.

69-04. Animal Type: cattle (dairy).
Injury: trauma due to panic, death due to trauma.
Number exposed/affected: / 3. Amount awarded: $0.00.

69-05. Animal Type: mink.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $0.00.

69-06. Animal Type: turkey.
Injury: smothering due to crowding, trauma due to panic.
Number exposed/affected: 13588 / 650. Amount awarded: $0.00.

70-01. Animal Type: mink.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $0.00.

70-03. Animal Type: mink.
Injury: abortion, killing/eating young.
Number exposed/affected: 533 / . Amount awarded: $0.00.

70-04. Animal Type: mink.
Injury: killing/eating young, reduced production (fur).
Number exposed/affected: / . Amount awarded: $0.00.

70-05. Animal Type: chicken.
Injury: trauma due to panic.
Number exposed/affected: 19530 / 660. Amount awarded: $0.00.

71-01. Animal Type: turkey.
Injury: smothering due to crowding, death due to trauma.
Number exposed/affected: 12480 / 1362. Amount awarded: $0.00.

71-02. Animal Type: cattle.
Injury: weight loss.
Number exposed/affected: 100 / 100. Amount awarded: $0.00.

71-02. Animal Type: sheep.
Injury: weight loss.
Number exposed/affected: 400 / 400. Amount awarded: $0.00.

71-02. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: 10 / 10. Amount awarded: $0.00.

71-02. Animal Type: goat.
Injury: weight loss.
Number exposed/affected: 15 / 15. Amount awarded: $0.00.

72-01. Animal Type: chicken.
Injury: reduced production (eggs), weight loss.
Number exposed/affected: 9334 / 9334. Amount awarded: $0.00.

72-02. Animal Type: chinchilla.
Injury: death due to trauma.
Number exposed/affected: / . Amount awarded: $0.00.

73-02. Animal Type: fox.
Injury: killing/eating young.
Number exposed/affected: / 57. Amount awarded: $0.00.

73-04. Animal Type: cattle.
Injury: weight loss, abortion, death due to trauma.
Number exposed/affected: / . Amount awarded: $2,500.00.

75-02. Animal Type: cattle.
Injury: weight loss (failure to gain), trauma due to panic.
Number exposed/affected: 162 / 162. Amount awarded: $20,398.15.

75-03. Animal Type: horse.
Injury: abortion.
Number exposed/affected: / 1. Amount awarded: $3,500.00.

76-01a. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: 4 / 3. Amount awarded: $0.00.

76-01b. Animal Type: horse.
Injury: traum due to panic.
Number exposed/affected: 4 / 3. Amount awarded: $0.00.

76-02. Animal Type: chicken.
Injury: reduced production (eggs).
Number exposed/affected: / . Amount awarded: $0.00.

77-02. Animal Type: cattle.
Injury: trauma due to panic, animal quality.
Number exposed/affected: / 1. Amount awarded: $1,400.00.

77-03. Animal Type: chicken.
Injury: smothering due to crowding.
Number exposed/affected: / 520. Amount awarded: $936.00.

77-04. Animal Type: dog.
Injury: death due to trauma.
Number exposed/affected: 1 / 1. Amount awarded: $0.00.

78-01. Animal Type: fox.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $0.00.

78-02. Animal Type: cattle.
Injury: trauma due to panic, death due to trauma.
Number exposed/affected: 253 / 253. Amount awarded: $288.00.

78-04. Animal Type: cattle.
Injury: weight loss.
Number exposed/affected: / . Amount awarded: $0.00.

79-01. Animal Type: chicken.
Injury: reduced production (eggs).
Number exposed/affected: 1173 / . Amount awarded: $0.00.

79-03. Animal Type: chicken.
Injury: reduced production (eggs).
Number exposed/affected: 12000 / . Amount awarded: $0.00.

79-04. Animal Type: horse.
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $0.00.

79-05. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: / . Amount awarded: $0.00.

79-07. Animal Type: cattle.
Injury: death due to trauma.
Number exposed/affected: 25 / 1. Amount awarded: $440.00.

79-08. Animal Type: horse.
Injury: trauma due to panic, reduced production.
Number exposed/affected: / 1. Amount awarded: $870.50.

79-09. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: / 1. Amount awarded: $575.00.

80-01. Animal Type: swine.
Injury: reduced production (piglets), abortion, death due to trauma.
Number exposed/affected: / 70. Amount awarded: $0.00.

80-02. Animal Type: chicken.
Injury: smothering due to crowding, death due to trauma.
Number exposed/affected: / 198. Amount awarded: $0.00.

80-03a. Animal Type: turkey.
Injury: smothering due to crowding.
Number exposed/affected: 16000 / 9363. Amount awarded: $110,000.00.

80-03b. Animal Type: turkey.
Injury: smothering due to crowding, weight loss.
Number exposed/affected: 28000 / 13134. Amount awarded: $0.00.

80-05. Animal Type: cattle.
Injury: death due to trauma, weight loss.
Number exposed/affected: 55 / 55. Amount awarded: $0.00.

80-06. Animal Type: duck.
Injury: reduced production (eggs).
Number exposed/affected: 27 / 27. Amount awarded: $0.00.

80-07. Animal Type: cattle.
Injury: death due to trauma.
Number exposed/affected: / 3. Amount awarded: $0.00.

80-11. Animal Type: rabbit.
Injury: trauma due to panic, reduced production.
Number exposed/affected: / 2. Amount awarded: $0.00.

81-01. Animal Type: cattle.
Injury: trauma, death due to panic, failure to gain, disappearance.
Number exposed/affected: / . Amount awarded: $17,772.57.

81-01. Animal Type: swine.
Injury: killing young, trauma due to panic.
Number exposed/affected: / . Amount awarded: $17,772.57.

81-02. Animal Type: mink.
Injury: trauma due to panic, abondoning young.
Number exposed/affected: / . Amount awarded: $0.00.

81-03. Animal Type: quail.
Injury: smothering due to crowding.
Number exposed/affected: / . Amount awarded: $0.00.

81-03. Animal Type: pheasant.
Injury: smothering due to crowding.
Number exposed/affected: / . Amount awarded: $0.00.

81-04. Animal Type: cattle.
Injury: unknown.
Number exposed/affected: / . Amount awarded: $3,260.00.

81-05. Animal Type: swine.
Injury: killing young.
Number exposed/affected: / 3. Amount awarded: $1,500.00.

81-06. Animal Type: cattle.
Injury: unknown.
Number exposed/affected: / . Amount awarded: $0.00.

81-07. Animal Type: horse.
Injury: unknown.
Number exposed/affected: / . Amount awarded: $0.00.

81-08. Animal Type: cattle.
Injury: unknown.
Number exposed/affected: / . Amount awarded: $500.00.

82-01. Animal Type: fox.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $0.00.

82-01. Animal Type: mink.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $0.00.

82-03. Animal Type: Unknown.
Injury: unknown.
Number exposed/affected: / . Amount awarded: $2,258.75.

83-01. Animal Type: swine.
Injury: trauma, death due to panic, abortion, animal quality.
Number exposed/affected: / 148. Amount awarded: $0.00.

83-02. Animal Type: bird (parrot).
Injury: breaking eggs during panic.
Number exposed/affected: / . Amount awarded: $0.00.

83-02. Animal Type: bird (parrot).
Injury: hatchability.
Number exposed/affected: / . Amount awarded: $0.00.

83-02. Animal Type: bird (parrot).
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $0.00.

83-02. Animal Type: bird (lory).
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $0.00.

83-03. Animal Type: cattle.
Injury: trauma, death due to panic, weight loss, reduced production.
Number exposed/affected: / 582. Amount awarded: $395,901.00.

83-04. Animal Type: cattle.
Injury: weight loss.
Number exposed/affected: / 170. Amount awarded: $0.00.

83-05. Animal Type: cattle.
Injury: weight loss.
Number exposed/affected: / 300. Amount awarded: $0.00.

83-06. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: / 5. Amount awarded: $0.00.

83-07. Animal Type: cattle (dairy).
Injury: poisoning.
Number exposed/affected: / . Amount awarded: $0.00.

83-08. Animal Type: exotic mammal (Beisa oryx).
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $1,200.00.

83-09. Animal Type: exotic mammal (gazelle).
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $2,000.00.

83-09. Animal Type: exotic mammal (eland).
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $2,000.00.

83-10. Animal Type: cattle.
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $0.00.

83-11. Animal Type: cattle.
Injury: weight loss.
Number exposed/affected: / . Amount awarded: $15,147.22.

83-12. Animal Type: turkey.
Injury: smothering due to crowding.
Number exposed/affected: / 482. Amount awarded: $2,972.61.

83-13. Animal Type: cattle (dairy).
Injury: reduced productivity (milk).
Number exposed/affected: / 16. Amount awarded: $6,705.50.

83-14. Animal Type: horse.
Injury: trauma due to panic, animal quality.
Number exposed/affected: / 2. Amount awarded: $600.00.

83-15. Animal Type: cattle.
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $1,147.00.

83-16. Animal Type: cattle.
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $330.40.

83-17. Animal Type: cattle.
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $396.50.

83-18. Animal Type: cattle.
Injury: death due to trauma.
Number exposed/affected: / 2. Amount awarded: $689.92.

84-01. Animal Type: turkey.
Injury: trauma due to panic.
Number exposed/affected: / . Amount awarded: $0.00.

84-02. Animal Type: cattle.
Injury: death due to trauma, weight loss.
Number exposed/affected: 145 / 145. Amount awarded: $0.00.

84-03. Animal Type: fox.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $0.00.

84-04. Animal Type: cattle.
Injury: weight loss.
Number exposed/affected: 162 / 162. Amount awarded: $0.00.

84-05. Animal Type: horse.
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $0.00.

84-06. Animal Type: swine.
Injury: death due to trauma, abortion.
Number exposed/affected: / 2. Amount awarded: $0.00.

84-07. Animal Type: fox.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $0.00.

84-08. Animal Type: horse.
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $709.50.

84-09. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: 3 / 1. Amount awarded: $2,060.00.

84-10. Animal Type: cattle.
Injury: trauma due to panic, animal quality.
Number exposed/affected: 14 / 1. Amount awarded: $679.91.

84-13. Animal Type: turkey.
Injury: traume due to panic.
Number exposed/affected: / . Amount awarded: $376.37.

84-14. Animal Type: cattle.
Injury: weight loss.
Number exposed/affected: 366 / 366. Amount awarded: $4,000.00.

84-15. Animal Type: cattle.
Injury: trauma due to panic, weight loss.
Number exposed/affected: 257 / 257. Amount awarded: $4,000.00.

84-16. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: / 1. Amount awarded: $45.00.

84-17. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: / 1. Amount awarded: $0.00.

84-18. Animal Type: fox.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $1,305.00.

84-19. Animal Type: cattle.
Injury: trauma due to panic, weight loss.
Number exposed/affected: / . Amount awarded: $636.20.

84-20. Animal Type: cattle.
Injury: animal quality.
Number exposed/affected: 46 / 46. Amount awarded: $0.00.

84-21. Animal Type: cattle.
Injury: death due to trauma.
Number exposed/affected: / 3. Amount awarded: $410.46.

85-02. Animal Type: chicken.
Injury: reduced production (eggs), death due to trauma.
Number exposed/affected: 4000 / 4000. Amount awarded: $0.00.

85-03. Animal Type: fox.
Injury: killing/eating young.
Number exposed/affected: / 1. Amount awarded: $0.00.

85-04. Animal Type: horse.
Injury: abortion.
Number exposed/affected: / 2. Amount awarded: $0.00.

85-05. Animal Type: turkey.
Injury: smothering due to crowding, weight loss.
Number exposed/affected: 10402 / 10402. Amount awarded: $0.00.

85-06. Animal Type: cattle.
Injury: abortion, trauma due to panic, death due to trauma.
Number exposed/affected: 512 / 28. Amount awarded: $0.00.

85-07. Animal Type: fox.
Injury: killing/eating young.
Number exposed/affected: / 5. Amount awarded: $2,040.00.

85-07. Animal Type: mink.
Injury: killing/eating young.
Number exposed/affected: / 14. Amount awarded: $2,040.00.

85-07. Animal Type: ferret.
Injury: killing/eating young.
Number exposed/affected: / 8. Amount awarded: $2,040.00.

85-08. Animal Type: cattle.
Injury: death due to trauma, trauma due to panic.
Number exposed/affected: 350 / 60. Amount awarded: $0.00.

85-09. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: / 1. Amount awarded: $0.00.

85-10. Animal Type: swine.
Injury: abortion, animal quality.
Number exposed/affected: / 5. Amount awarded: $2,405.58.

85-11. Animal Type: fox.
Injury: trauma due to panic, killing/eating young.
Number exposed/affected: / . Amount awarded: $0.00.

85-11. Animal Type: exotic mammal (lynx).
Injury: death due to trauma.
Number exposed/affected: / 3. Amount awarded: $0.00.

85-11. Animal Type: exotic mammal (cougar).
Injury: abortion.
Number exposed/affected: / 1. Amount awarded: $0.00.

85-12. Animal Type: cattle.
Injury: failure to gain weight.
Number exposed/affected: 71 / 71. Amount awarded: $0.00.

85-13. Animal Type: horse.
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $1,500.00.

85-14. Animal Type: cattle.
Injury: trauma due to panic.
Number exposed/affected: / 29. Amount awarded: $895.00.

85-15. Animal Type: cattle (dairy).
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $926.93.

85-16. Animal Type: exotic mammal (antelope).
Injury: death due to trauma.
Number exposed/affected: / 2. Amount awarded: $4,200.00.

85-16. Animal Type: exotic mammal (zebra).
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $4,200.00.

85-16. Animal Type: exotic mammal (antelope).
Injury: death due to trauma.
Number exposed/affected: / 1. Amount awarded: $4,200.00.

85-17. Animal Type: mink.
Injury: killing/eating young.
Number exposed/affected: / 23. Amount awarded: $0.00.

86-01. Animal Type: cattle.
Injury: disappearance, weight loss.
Number exposed/affected: 125 / 125. Amount awarded: $0.00.

86-02. Animal Type: cattle (dairy).
Injury: trauma due to panic, loss of productivity.
Number exposed/affected: 80 / 3. Amount awarded: $742.91.

86-03. Animal Type: sheep.
Injury: Death due to trauma.
Number exposed/affected: / 23. Amount awarded: $0.00.

86-04. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: / 2. Amount awarded: $10,000.00.

86-05. Animal Type: bird (cockatoo).
Injury: hatchability.
Number exposed/affected: / . Amount awarded: $0.00.

86-05. Animal Type: bird (conure).
Injury: hatchability.
Number exposed/affected: / . Amount awarded: $0.00.

86-06. Animal Type: cattle.
Injury: trauma due to panic, weight loss, disappearance.
Number exposed/affected: 600 / 600. Amount awarded: $1,620.18.

86-07. Animal Type: cattle.
Injury: trauma due to panic, death due to trauma, weight loss.
Number exposed/affected: 170 / 170. Amount awarded: $3,757.50.

86-08. Animal Type: cattle.
Injury: death due to trauma, trauma due to panic, weight loss.
Number exposed/affected: 325 / 325. Amount awarded: $6,456.12.

87-00. Animal Type: sheep.
Injury: reduced production (wool), death due to trauma.
Number exposed/affected: 300 / . Amount awarded: $0.00.

88-00. Animal Type: cattle.
Injury: trauma due to panic, death due to trauma, animal quality.
Number exposed/affected: 197 / 66. Amount awarded: $0.00.

88-01a. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: 4 / 1. Amount awarded: $0.00.

88-01b. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: 4 / . Amount awarded: $0.00.

88-02. Animal Type: chicken.
Injury: reduced production (eggs), smothering due to crowding.
Number exposed/affected: 4300 / 4300. Amount awarded: $0.00.

88-04. Animal Type: horse.
Injury: trauma due to panic.
Number exposed/affected: / 3. Amount awarded: $0.00.

88-05. Animal Type: fox.
Injury: killing/eating young.
Number exposed/affected: 26 / 3. Amount awarded: $0.00.

88-06. Animal Type: cattle (dairy).
Injury: reduced production (milk).
Number exposed/affected: / . Amount awarded: $0.00.

88-07. Animal Type: fox.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $0.00.

88-08. Animal Type: poultry.
Injury: hatchability.
Number exposed/affected: / . Amount awarded: $0.00.

88-09. Animal Type: fox.
Injury: killing/eating young.
Number exposed/affected: / . Amount awarded: $0.00.

88-10. Animal Type: turkey.
Injury: smothering due to crowding, death due to trauma.
Number exposed/affected: / 34. Amount awarded: $1,264.80.

88-11. Animal Type: goat.
Injury: debris injestion.
Number exposed/affected: / 5. Amount awarded: $0.00.

APPENDIX 3

Table giving the effects of noise that have been suggested, the species that would be affected, the best method for determining whether the effect occurs, the probability that it occurs and the type of management environment in which it would be found. This appendix summarizes the results of a series of meetings with animal health professionals to assess the potential for noise effects.

This table summarizes the discussions in a meeting with four experts from the School of Veterinary Medicine, Animal Science and Epidemiology at the University of California at Davis (Drs. M. Bruss, G. Moberg, D. Hird, M. Fry). It lists the effects that have been documented to some extent in the literature, ways that these effects could be measured, type of study that would be required to demonstrate the effect, an evaluation of whether or not the effect is likely to occur (at all), and the agricultural environments in which this effect is likely to occur. Note that there are two tables for each type of animal. The first treats animals under normal circumstances (i.e. the most commonly-held breeds in standard housing), the second treats animals that have been previously-stressed by disease, environmental conditions, or genetic conditions that predispose them to effects from acute stress.

Note that these assessments are based on the presumption that on the MTR's sorties may be flown over animals with little previous exposure to aircraft noise (naive) at low altitude for periods of up to several months (for example 100 overflights scattered over a period of 1-2 months), but that exposure will not be high when measured over the course of a year (5-10 flights/day as an outside estimate). The table lists the probability that each type of effect **could** occur, but does not imply how often. The ratings are based on documented effects from the literature and on the consultant's experience with other types of stressors. In some cases, the probabilities are informed guesses based on the effects of other types of startling stimuli (e.g. electric shocks).

Probability ratings of effects are as follows. They are intended to be as conservative as possible:

IMPROBABLE = no good evidence that the effect will be observed at all (never observed in properly controlled studies, unlikely to occur due to normal management practices, never documented clinically, observed only in studies without appropriate controls or in poorly substantiated in the claims against the Air Force)

POSSIBLE = some chance that the effect may occur, at least in a few individuals. These effects were not observed in properly controlled studies, but are documented well in claims or clinical reports. The behavior or condition that might give rise to effect is observed in response to startling stimuli.

PROBABLE = the effect is likely to occur, at least in a few naive individuals. The effect is observed in properly-controlled studies, and the mechanism of effect is well-documented. The effect has been the subject of well-documented claims deemed legitimate by Air Force Veterinarians. The mechanism of the effect is well-understood and well-documented)

EFFECTS ON LARGE STOCK (FARM HORSES, BEEF CATTLE, SHEEP, GOATS, EXOTIC DOMESTICS [ELAND])

NOTE: # denotes "number of"; probability ratings explained above

Effect	Measure	Approach	Probability that effect can occur	Management Environment
ABORTION	# still births; # premature; # fetuses resorbed	epidemiological; controlled study with simulated aircraft noise	IMPROBABLE	feedlot; range; farm
TRAUMA	# injuries (death or life-threatening injuries very unlikely)	controlled study with simulated aircraft noise or overflights	PROBABLE	feedlot; farm; range
CHANGE IN GROWTH EFFICIENCY	cost of food input/unit weight output	controlled study with simulated aircraft noise	IMPROBABLE	feedlot
WEIGHT IMPROBABLE OR REDUCED WEIGHT GAIN	change in body weight; carcass condemnation rates	controlled study with simulated aircraft noise; epidemiological	IMPROBABLE	feedlot; range
DECLINE IN REPRODUCTIVE OUTPUT	# fetuses resorbed; fertility; # young produced	epidemiological	IMPROBABLE	range

PROPERTY DAMAGE	dollar value of damages due to animal activity	epidemiological	PROBABLE	feedlot; farm
PARENTAL NEGLIGENCE	changes in parenting behaviors; weight of young at weaning	controlled study with simulated aircraft noise	IMPROBABLE	range; farm

For each effect categorized as "possible" or "probable", we suggest species and breeds that might be susceptible:

TRAUMA - Brahma (Zebu) cattle, especially bulls.

DAIRY ANIMALS (CATTLE, GOATS)

Effect	Measure	Approach	Probability that effect could be observed	Management Environment
ABORTION	#still births; #premature; #fetuses resorbed	epidemiological	IMPROBABLE	dairy
MILK PRODUCTION DECLINES	lbs milk produced; milk composition	longitudinal data on individuals	IMPROBABLE	dairy ; high-production dairy
TRAUMA	# injuries	simulation; real overflights	POSSIBLE	dairy
CHANGE IN MILK PRODUCTION EFFICIENCY	cost of food input/milk weight output	epidemiological	IMPROBABLE	dairy; high-production dairy
SHORT-TERM EFFECT ON MILK LET-DOWN	lbs milk produced; milk composition	longitudinal data on individuals	POSSIBLE	dairy
DECLINE IN REPRODUCTIVE OUTPUT	# fetuses resorbed; fertility; duration of non-pregnant periods	epidemiological	IMPROBABLE	dairy; high-production dairy

PROPERTY DAMAGE	dollar value of damages due to animal activity	epidemiolo- gical	POSSIBLE	dairy

For each effect categorized as "possible" or "probable", we suggest species and breeds that might be susceptible:

TRAUMA/PROPERTY DAMAGE: Dairy cattle are generally very even-tempered. As a result, the likelihood of stampeding is small. Holstein cattle produce 90% of the milk in the U.S. and Canada; therefore they are the most general model available. However, the milking shorthorn cow is probably a better "worst case model" because it is less even-tempered. Jerseys or Guernseys would be good for similar reasons.

SHORT-TERM EFFECT ON MILK LET-DOWN: This is likely to be observed in dairy cattle just before milking. Some high-production dairies monitor the production of each cow mechanically, allowing individual productivity to be recorded daily. Short-term effects could be observed in such a dairy.

EFFECTS ON "PRE-STRESSED" DAIRY ANIMALS (CATTLE, GOATS)

Effect	Measure	Approach	Probability that effect could be observed	Management Environment
ABORTION	#still births; #premature; #fetuses resorbed	epidemiological	IMPROBABLE	dairy
DECLINE IN MILK PRODUCTION	lbs milk produced; milk composition	longitudinal data on individuals	POSSIBLE	dairy
SHORT-TERM EFFECT ON MILK LET-DOWN	lbs milk produced; milk composition	longitudinal data on individuals	POSSIBLE	dairy
SUDDEN DEATH OR PROSTRATION	# number of deaths or prostrations	epidemiological	IMPROBABLE	high-production dairy
CHANGE IN MILK PRODUCTION EFFICIENCY	cost of food input/milk weight output	epidemiological	PROBABLE	high production dairy
DECLINE IN REPRODUCTIVE OUTPUT	# fetuses resorbed; fertility	epidemiological	POSSIBLE	dairy; high-production dairy

For each effect categorized as "possible" or "probable", we suggest species and breeds that might be susceptible:

CHANGES IN MILK PRODUCTION: Dairy cows, most particularly high-production dairy cattle are occasionally susceptible to ketosis, as condition that causes the cattle to cease producing milk. A cow susceptible to ketosis could cease production as a result of aircraft overflights. Cattle prone to ketosis would probably be the best models for experimental studies.

Cattle with brucellosis may also cease production under similar circumstances. Brucellosis has been eliminated in most areas, and is therefore not generally an important stressor.

Note, however that dairy cattle with "hardware disease" (i.e. that have eaten sharp objects), a displaced abomasum, or suffering from heat stress may be much more susceptible to loss of production due to disturbance.

EFFECTS ON "PRE-STRESSED" MEAT ANIMALS (CATTLE, SHEEP)

Effect	Measure	Approach	Probability that effect could be observed	Management Environment
SUDDEN DEATH OR PROSTRATION	# number of deaths or prostrations	epidemiological	POSSIBLE	range
CHANGE IN PRODUCTION EFFICIENCY	cost of food input/weight output	simulations	POSSIBLE	feedlot; range
DECLINE IN REPRODUCTIVE OUTPUT	# fetuses resorbed; fertility	epidemiological	POSSIBLE	range
PARENTAL NEGLIGENCE	changes in parenting behaviors; weight of young at weaning	simulated aircraft noise	IMPROBABLE	range

For each effect categorized as "possible" or "probable", we suggest species and breeds that might be susceptible:

CHANGES IN PRODUCTION EFFICIENCY: Good models for stressed cattle would be weanling beef cattle with "shipping fever" (pneumonia or other pulmonary problems due to transport) in feedlots.

DECLINES IN PRODUCTIVITY: Beef cows: cows under great heat or dehydration stress might be shocked into loss of productivity by a serious fright; cows with "cow asthma" (cows with an immunological problem caused by a switch in pasture type); cows with urolithiasis or dehydration due to sudden cold snap or storm; dehydrated cows.

SUDDEN DEATH: Ewes: pregnant sheep that have been chilled, especially recently shorn ewes, can die of pregnancy toxemia after a shock (they are

prone to this anyway). Sheep in cold mountain areas are most susceptible due to unpredictable spring weather.

LONG TERM, FREQUENT EXPOSURE TO LOW LEVEL OVERFLIGHTS (E.G. UNDER TAKEOFF AND LANDING PATHWAYS FROM A MAJOR BASE

Effect	Measure	Approach	Probability that effect could be observed	Management Environment
CHANGE IN PRODUCTION EFFICIENCY	cost of food input/weight output	simulations	POSSIBLE	feedlot; range; dairy
DECLINE IN REPRODUCTIVE OUTPUT	# fetuses resorbed; fertility	epidemiological	POSSIBLE	range; dairy
PARENTAL NEGLIGENCE	changes in parenting behaviors; weight of young at weaning	epidemiological	IMPROBABLE	range; pig farm
FAILURE TO GAIN	change in body weight by day	epidemiological	IMPROBABLE	range; feedlot
REDUCED HEALTH	incidence of diseases (must have matched controls); parasite loads;	epidemiological	IMPROBABLE	feedlot; any crowded farm

For each effect categorized as "possible" or "probable", we suggest species and breeds that might be susceptible: see lists under specific headings above. There is no evidence for these types of effects.

EFFECTS ON PIGS

Effect	Measure	Approach	Probability that effect could be observed	Management Environment
MATERNAL NEGLIGENCE OR ABUSE	# piglets surviving; weight of litter at weaning; changes in behaviors	controlled study with simulated overflights	POSSIBLE	pig farm
DECLINE IN REPRODUCTIVE OUTPUT	# fetuses resorbed; fertility	epidemiological	POSSIBLE	pig farm; farrowing crate
FAILURE TO GAIN; "PRODUCTION DISEASE"	change in body weight by day	epidemiological	IMPROBABLE	pigsty
TRAUMA	number of injuries; agonistic encounters	controlled studies with simulated or actual overflights	PROBABLE	pig farm
ABORTIONS	# stillborn; # premature births	epidemiological	IMPROBABLE	pig farm; farrowing crate
PROPERTY DAMAGE	dollars in damage	simulated overflights	IMPROBABLE	pig farm

AGGRESSIVE INJURIES OR "VICES" THAT CAUSE INJURY	# agonistic encounters; incidence of "vices"	simulated overflights	IMPROBABLE	pig farm; farrowing crate

NOTE: a pig farm is generally an open operation, whereas farrowing crates are typical of confined operations. There is some prospect that pigs in an open operation could see aircraft.

For each effect categorized as "possible" or "probable", we suggest species and breeds that might be susceptible:

NEGLIGENT MATERNAL CARE: Crushing is a major cause of piglet death. Startling mothers with newborns would be the most sensitive test of this possible effect.

AGGRESSION OR VICE RELATED INJURIES: Feeder pigs are most likely to show injuries related to aggression (tail biting and fighting).

EFFECTS ON PIGS - DAMAGES TO "PRE-STRESSED" INDIVIDUALS

Effect	Measure	Approach	Probability that effect could be observed	Management Environment
SOW FAILS TO FEED, NEGLECTS OR ABUSES PIGLETS	# piglets surviving; weight of litter at weaning; changes in behaviors	controlled study using simulated aircraft noise	PROBABLE	open pig farm
DECLINE IN REPRODUCTIVE OUTPUT	# fetuses resorbed; fertility	epidemiological	POSSIBLE	open pig farm; farrowing crates
FAILURE TO GAIN; "PRODUCTION DISEASE"	change in body weight by day	epidemiological	IMPROBABLE	open pig farm
SUDDEN DEATH	# deaths	controlled study with simulated aircraft noise	PROBABLE	open pig farm; farrowing crates
ABORTIONS	# stillborn; # premature births	epidemiological	IMPROBABLE	open pig farm; farrowing crates

For each effect categorized as "possible" or "probable", we suggest species and breeds that might be susceptible:

SUDDEN DEATH: Pigs with Porcine Stress Syndrome.

FAILURE TO GAIN and REPRODUCTIVE DECLINES: sows with a-galactia syndrome, sows with mastitis or metritis, sows undergoing a number of stresses simultaneously (heat, humidity, water deprivation, transport, handling, etc.)

EFFECTS ON FOWL (TURKEYS, CHICKENS, FARM PHEASANTS, FARM QUAIL)

Effect	Measure	Approach	Probability that effect could be observed	Management Environment
CHANGES IN EGG PRODUCTION	# eggs produced; weight of eggs; reproductive lifespan	simulations	IMPROBABLE	housed on floor housed; caged
MORTALITY DUE TO CROWDING OR PILING	# found dead per day	controlled study using simulated aircraft noise and actual overflights	IMPROBABLE	floor housed
EGG CONSUMPTION	change in egg production rate per hen	controlled study using simulated aircraft noise	IMPROBABLE	floor housed
INJURIES DUE TO AGGRESSION	numbers of chickens dead or injured	epidemiological	IMPROBABLE	floor housed chickens without trimmed beaks

EFFECTS ON "PRE-STRESSED" FOWL (TURKEYS, CHICKENS, FARM PHEASANTS, FARM QUAIL)

Effect	Measure	Approach	Probability that effect could be observed	Management Environment
CHANGES IN EGG PRODUCTION DUE TO PREMATURE MOLT	# eggs produced; weight of eggs; molt condition	controlled experiments with simulated aircraft noise	POSSIBLE	floor housed; caged
MORTALITY DUE TO CROWDING OR PILING	# found dead per day	controlled experiments with simulated aircraft noise AND actual aircraft overflights	PROBABLE	floor housed
"PRODUCTIVITY DISEASE" (SHORT PRODUCTIVE LIFESPAN; FAILURE TO GAIN)	# eggs produced; uniformity of weight at slaughter	epidemiological	POSSIBLE	floor housed; caged

For each effect categorized as "possible" or "probable", we suggest species and breeds that might be susceptible:

CROWDING OR PILING: Fowl kept in the open in large groups, particularly turkeys in large modern herds, especially if under environmental stress (e.g. water stressed or heat stressed for many days); "hysterical" white leghorns (high-production broilers)

CHANGES IN PRODUCTION DUE TO PREMATURE MOLT: Dehydrated chickens are prone to premature molt, which stops production; chickens with fowl cholera.

PRODUCTIVITY DISEASE: Problem farms may be identified by measuring uniformity of weight at slaughter or at numbers of carcasses condemned or rejected at slaughter (since most automated carcass-handling machinery demands uniform size).

EFFECTS OF AIRCRAFT OVERFLIGHTS ON PETS OR WORKING DOGS (INSUFFICIENT DATA FOR MODEL)

Effect	Measure	Approach	Probability that effect could be observed	Management Environment
AUDITORY DAMAGE	permanent threshold shifts	survey of veterinary records	IMPROBABLE	home; sheep farm
CHANGES IN TEMPERAMENT	"vices"; increased aggression; fear of loud sounds	epidemiological; experimental measures of temperament	UNKNOWN	home; special environments

APPENDIX 4

FIGURES AND TABLES

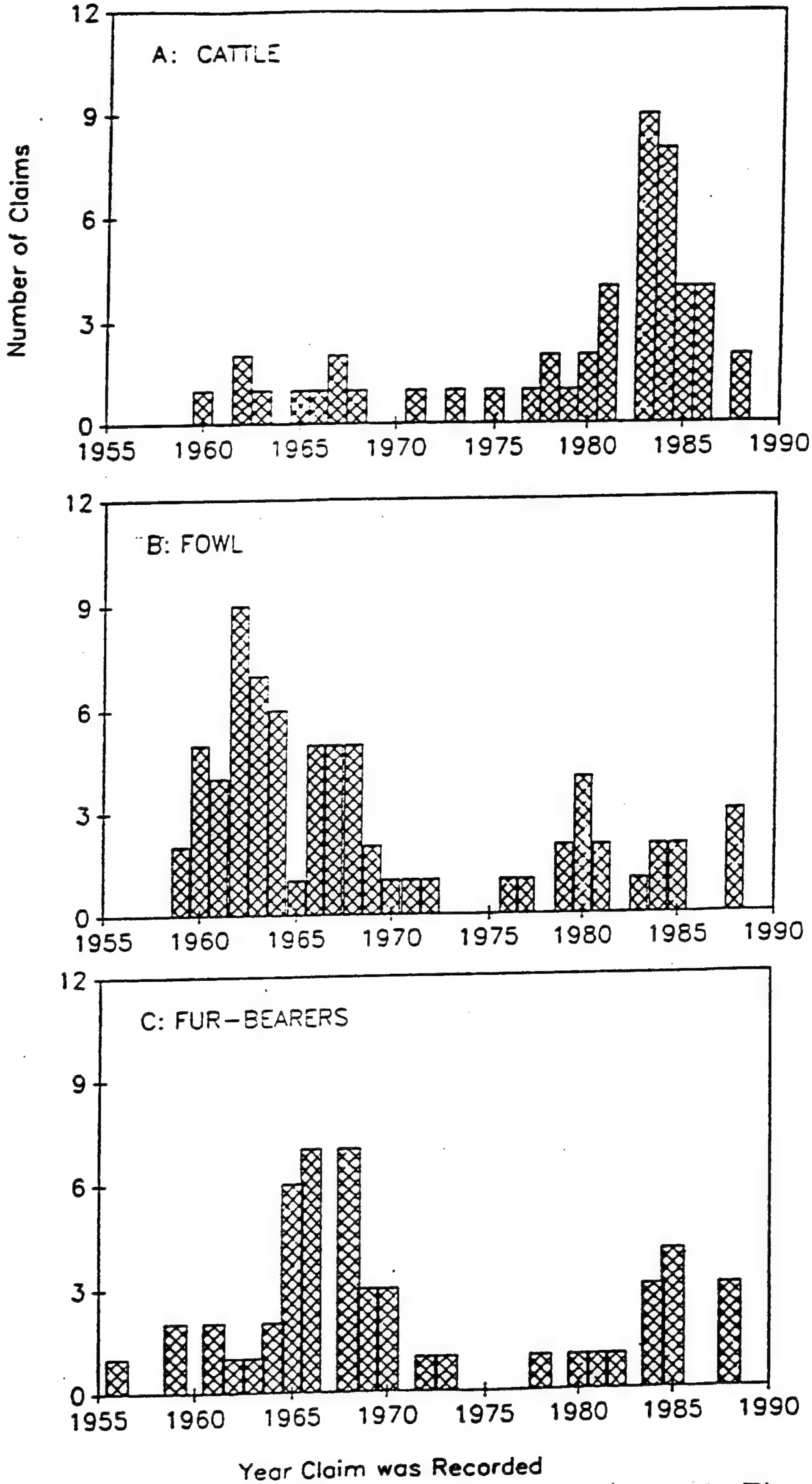

Figure 1: Number of claims per year for damages to (A) cattle, (B) fowl, and (C) fur-bearing animals.

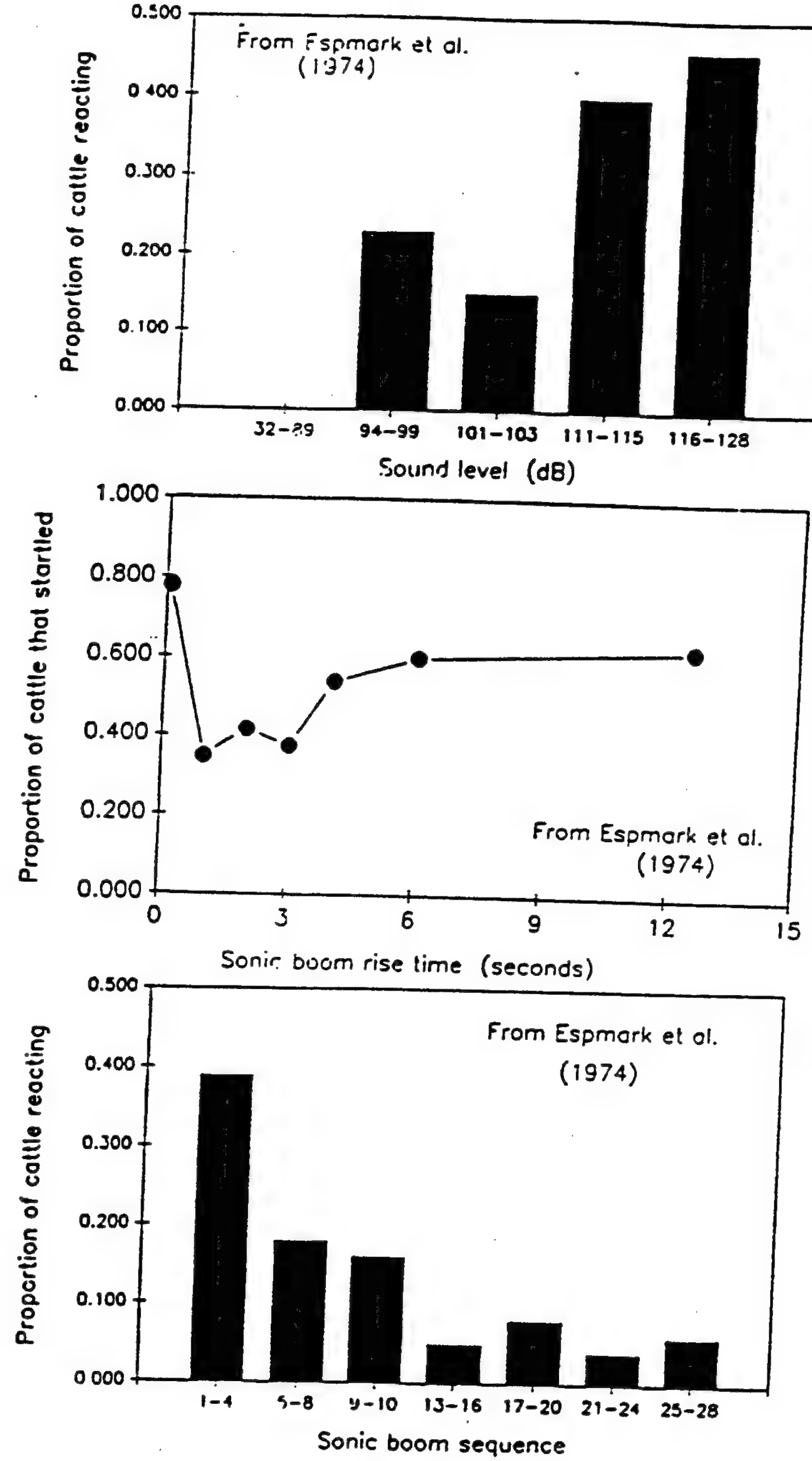

Figure 2: Results of dose-response measurements made by Espmark et al. 1974. These summary figures include only the data on strong responses of animals. (A) Relation between sound level of overflight and proportion of cattle responding. (B) Relation between sonic boom rise-time and proportion of cattle startled. (C) Relation between order of overflight in a sequence and proportion of cattle responding.

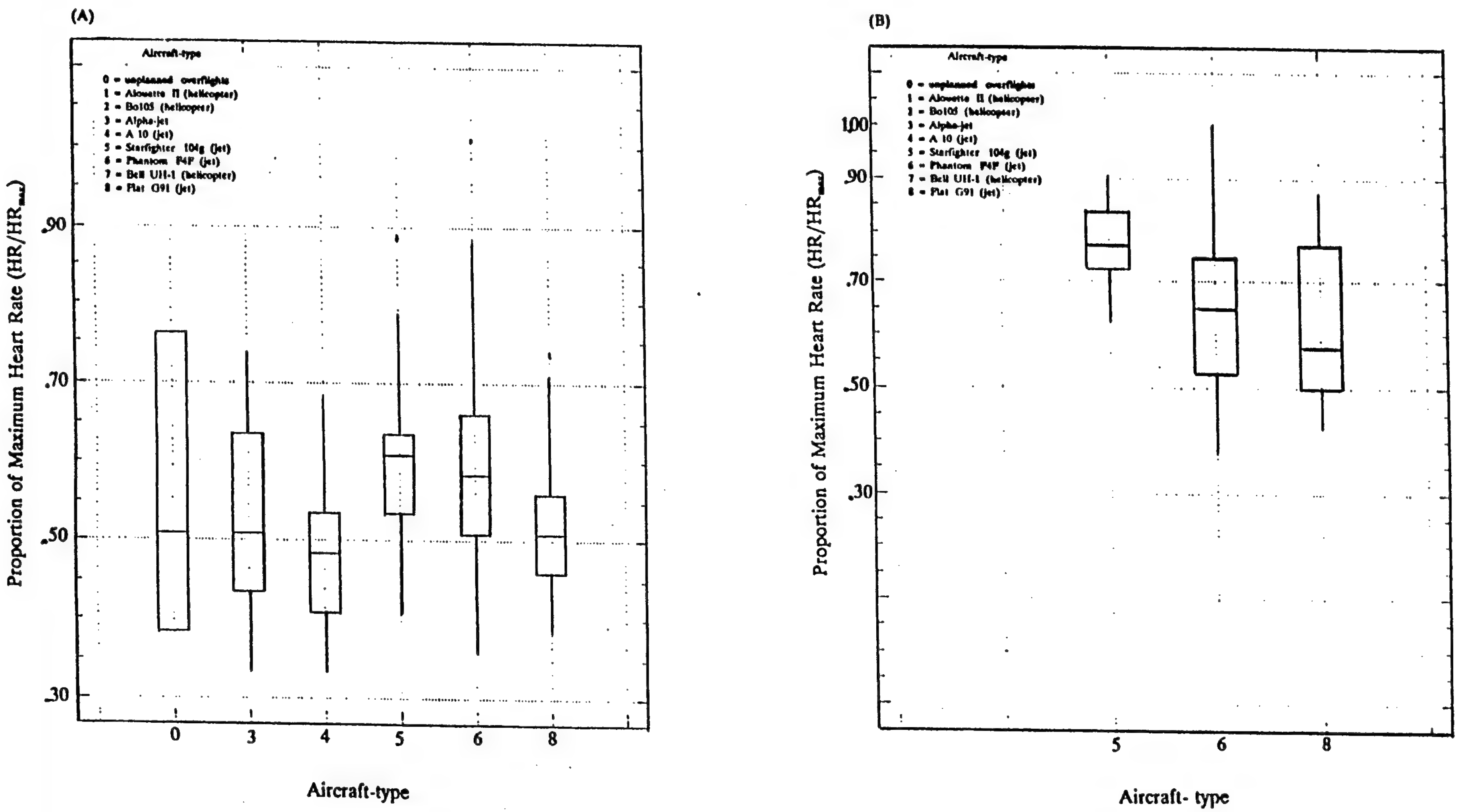

Figure 3: Effect of aircraft type on heart rate responses of (A) cattle and (B) horses. These data are from Beyer (1983), Heuweiser (1982), Erath (1983), and Kruger (1983).

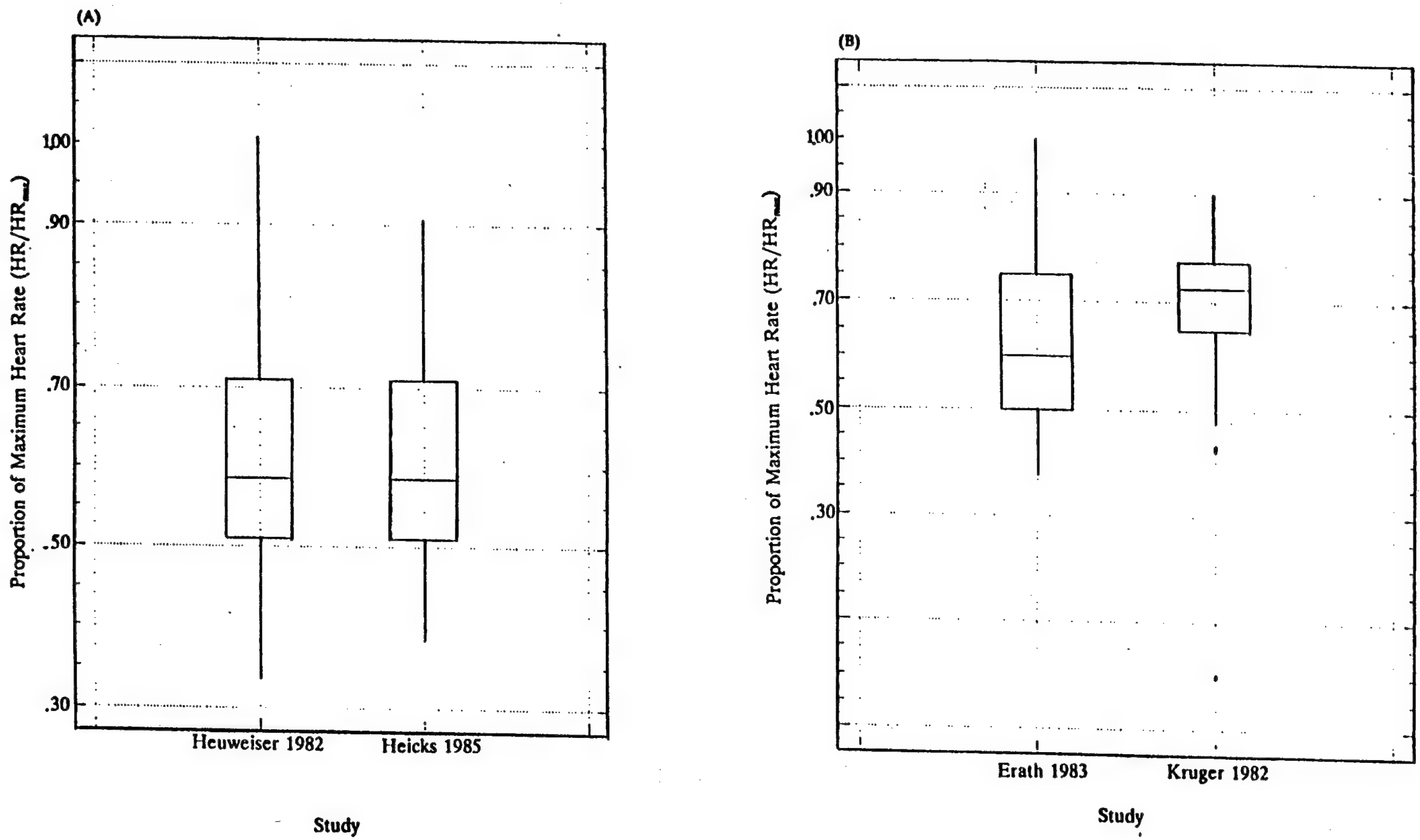

Figure 4: Effect of differences in study methods on heart rate responses of (A) cattle and (B) horses. These data are from Heicks (1985), Heuweiser (1982), Erath (1983), and Kruger (1983).

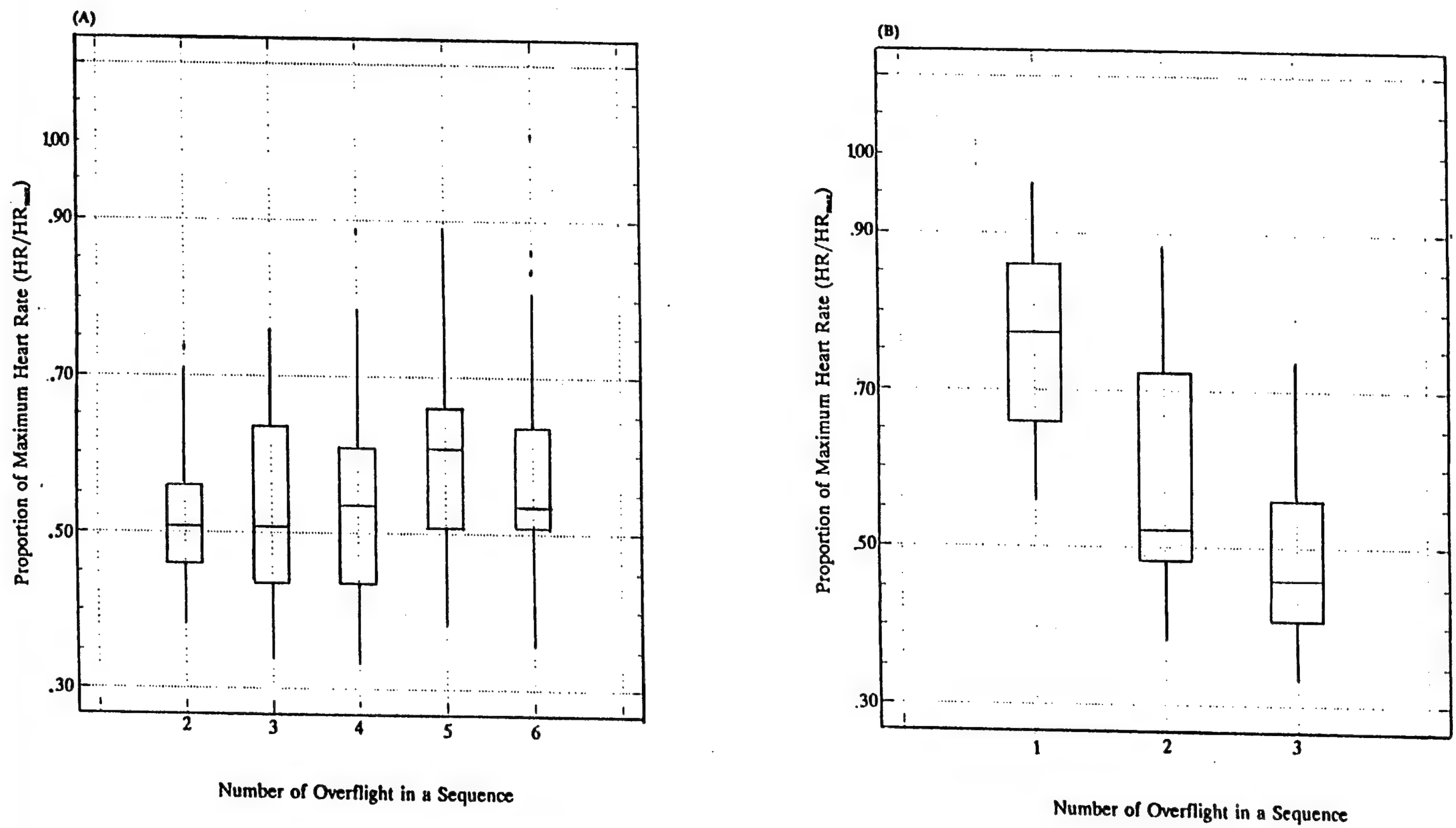

Figure 5: Effect of number of overflight in a sequence on heart rate responses of (A) cattle and (B) horses. These data are from Beyer (1983), Heuweiser (1982), Erath (1983), and Kruger (1983).

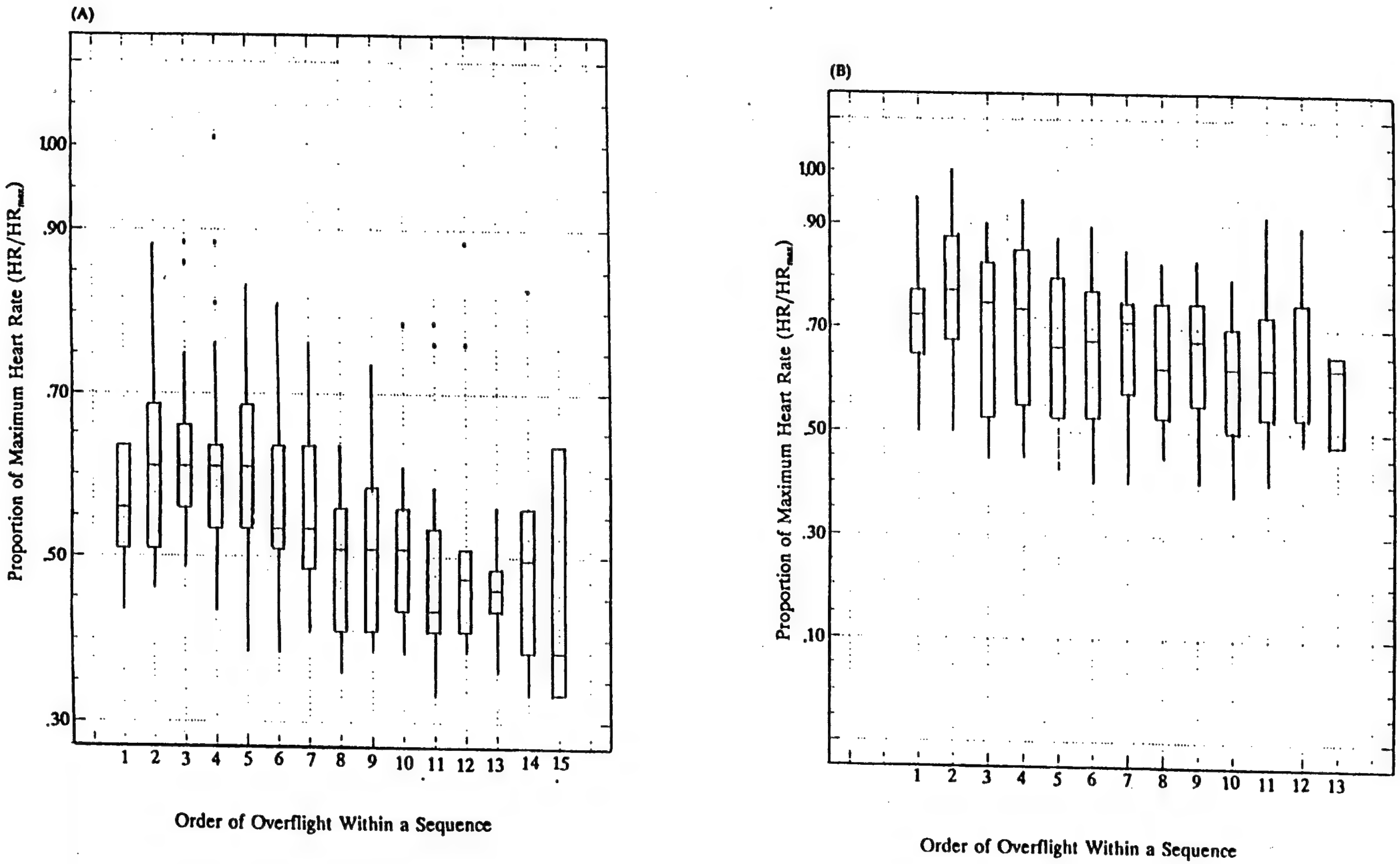

Figure 6: Effect of order of overflight in a sequence on heart rate responses of (A) cattle and (B) horses. These data are from Beyer (1983), Heuweiser (1982), Erath (1983), and Kruger (1983).

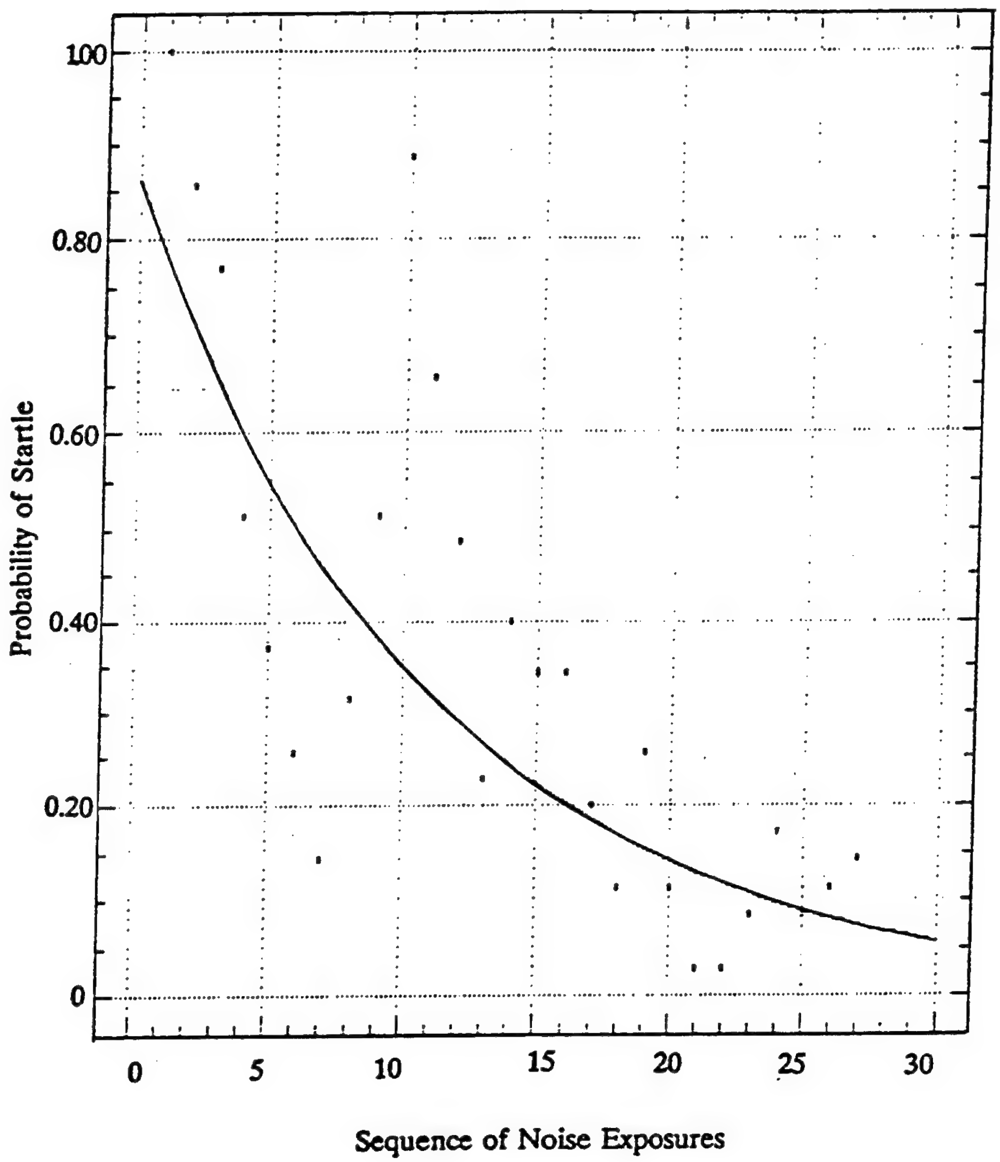

Figure 7: Habituation rate of humans to repeated exposure to very high amplitude, rapid-onset tone bursts (115 dB at 1000 Hz with rise-time 2.5 ms). Data are summarized from Hoffman and Searle (1968).

DESIGN FOR DOMESTIC ANIMAL MODEL

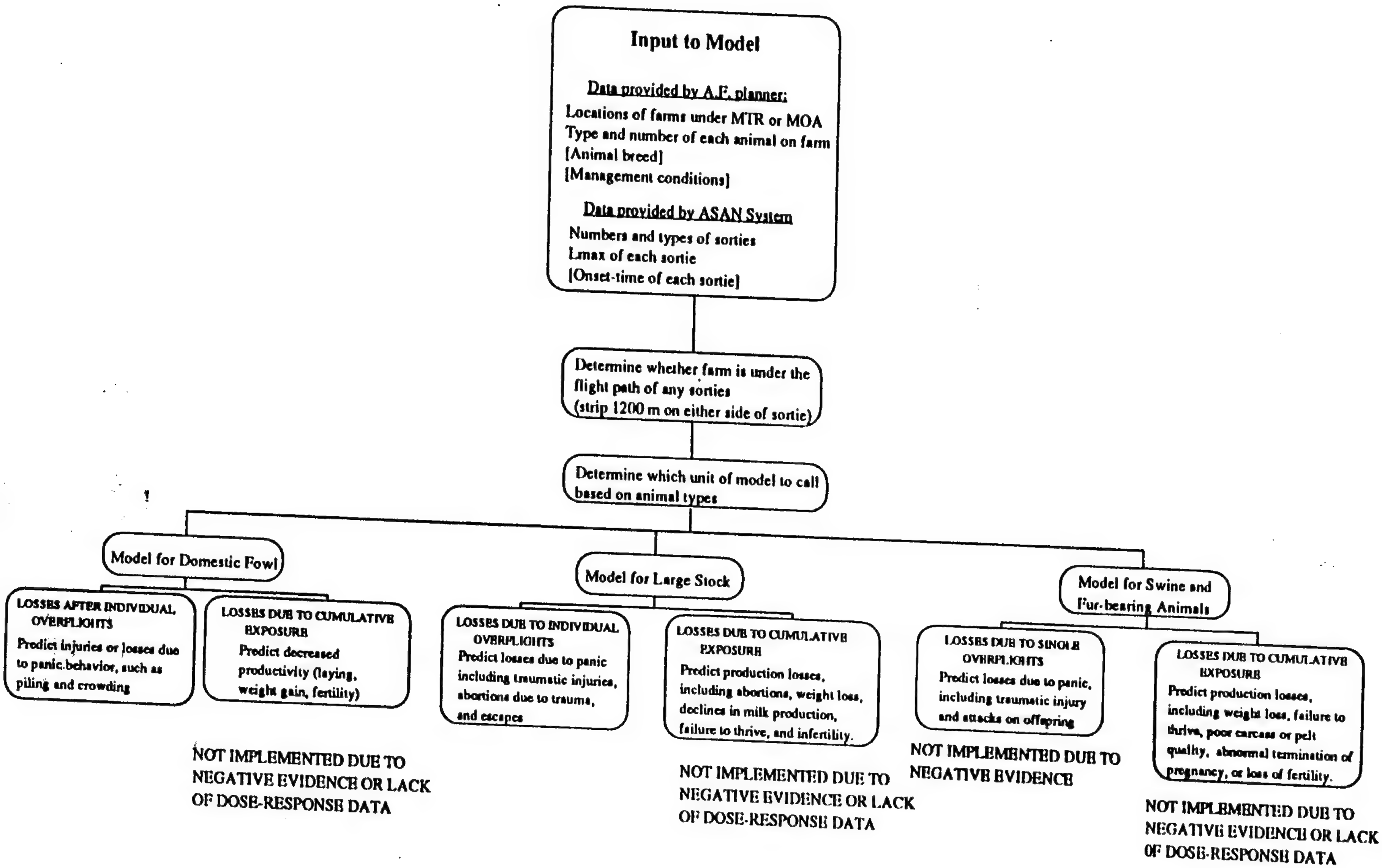

Figure 8: Schematic of model for the effects of noise on domestic animals. Portions of the model were not implemented either because all the existing experimental evidence indicated that the effect does not occur (negative evidence) or because data were lacking entirely.

Model for domestic livestock: losses after single overflights

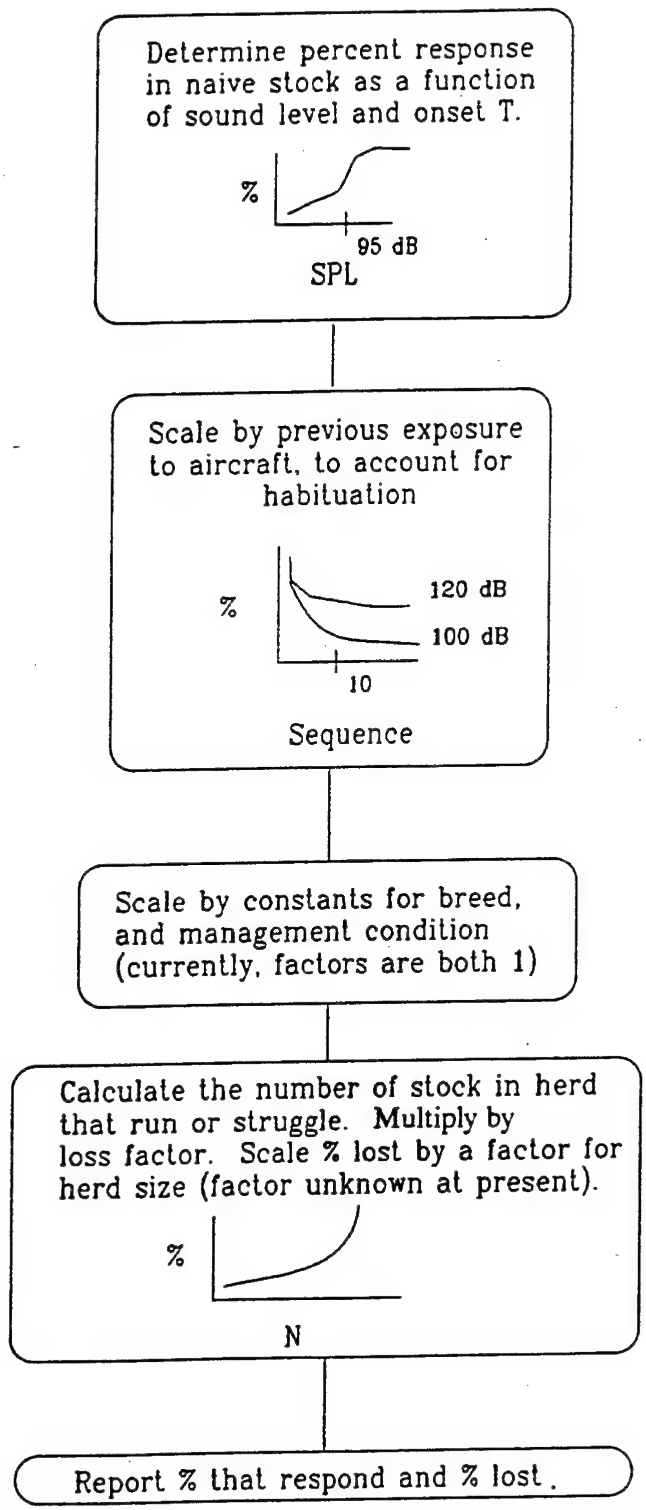

Figure 9: Schematic of model for the effects of single overflights on losses in large domestic stock. At this point, many of the relations in the model are estimates based on little data. The relation between herd size and percent loss is unknown. These relations will be added or improved as data become available.

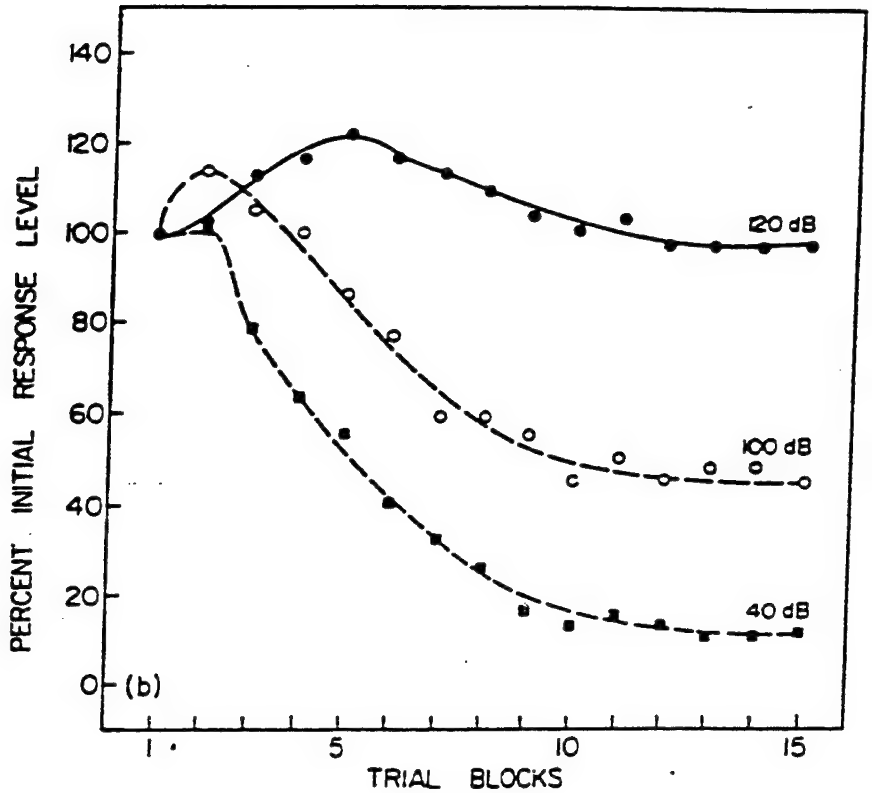

Figure 10: Relation between sound level, number of exposures and percent responses. This relation is drawn from data on laboratory animals (Peeke and Herz 1973).

Model for domestic fowl: losses after single overflights

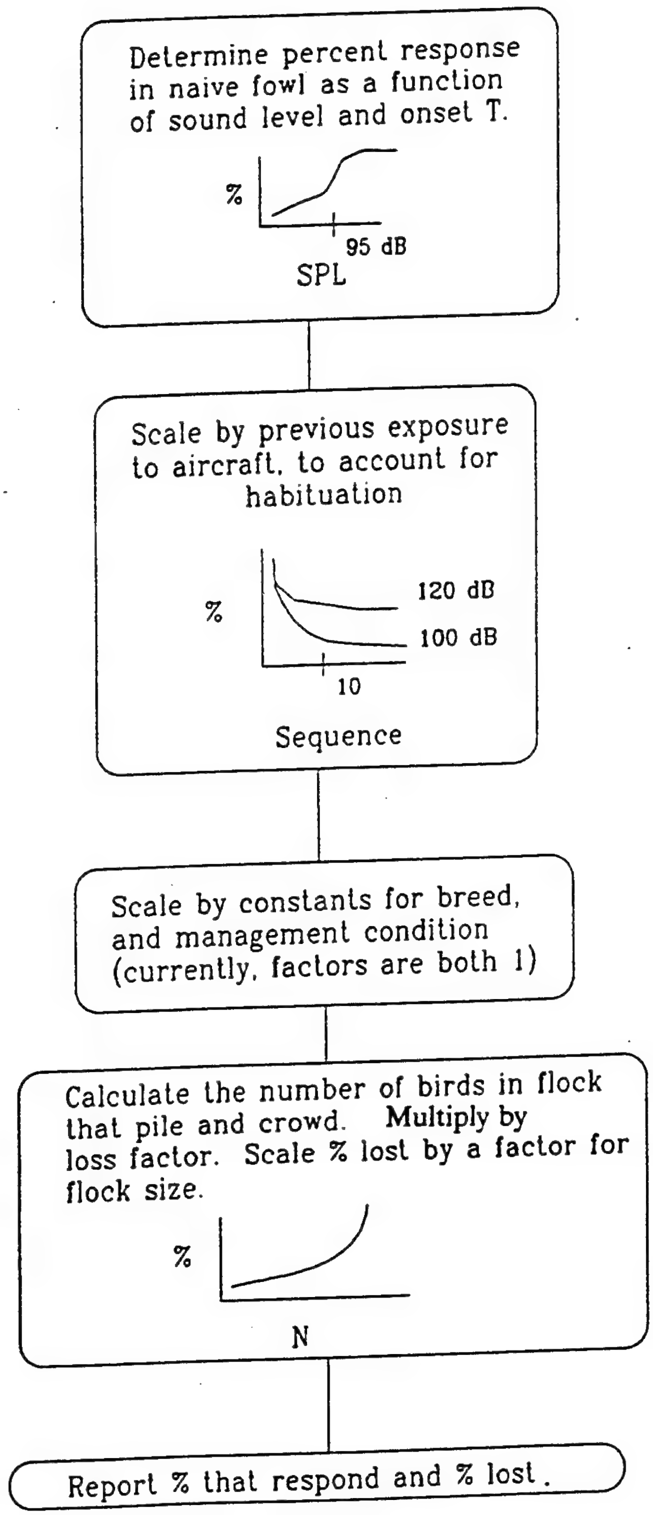

Figure 11: Schematic of model for the effedts of single overflights on domestic fowl.

Table 1. Breakdown of the dollar amounts claimed and approved (summarized by species) from the U.S. Air Force claims files.

Animal Category	Total # Claims	# Claims w/ Amt. Claimed Unknown	Dollar Value Claimed	Dollar Value Approved
Fur Bearer	51	8	$1,002,400	$77,308
Mink only*	36	7	911,908	76,003
Fowl	73	12	698,241	158,223
Cattle				
beef	48	6	**675,997	**485,213
dairy	11	3	30,622	9,756
Horse	35	7	***669,075	23,401
Sheep	4	2	1,445	-0-
Swine	6	2	45,305	21,678
Goat	2	1	1,235	-0-
Fish	3	0	86,968	-0-
Exotic Bird	4	1	5,200	-0-
Exotic Mammal	4	1	7,400	7,400
Wild Mammal	1	0	1,000	-0-
Dog	4	1	1,759	-0-
TOTALS	241	42	3,226,647	782,979

* subset of fur bearers
** $395,901 was claimed and paid in one claim
*** $376,266 was for personal injury in one claim

Table 2. Numbers of animals reportedly exposed to and affected by the aircraft activity. The claims included on this table reported both the number of animals exposed and the number affected.

Animal Type	# Claims	# Exposed	# Adults Affected	# Young eaten/killed
Fur Bearer	5	1707	553	2225
Mink only*		1148	408	1569
Fowl	24	212,919	96,449	
Cattle				
Beef	22	4130	3188	
Dairy	3	206	70	
Horse	9	32	23	
Sheep	1	400	400	
Swine	0	n/a	n/a	
Goat	1	15	15	
Fish	1	570	570	
Exotic Bird	1	1	1	
Exotic Mammal	0	n/a	n/a	
Wild Mammal	0	n/a	n/a	
Dog	4	4	4	

* subset of fur bearers

Table 3. Aircraft activity that caused claims. Numbers of claims for each type of activity are listed by animal grouping.

	Disturbance Type					
Animal Type	Low Level Overflight	Sonic Boom	Crash	Ground Traffic	Other	Unknown
Fur Bearer	30	18	1	0	0	2
mink only*	20	13				2
Fowl	35	30	4	0	0	5
Cattle						
beef	30	5	5	2	**1	7
dairy	6	2	2	0	**1	0
Horse	20	10	1	0	***1	3
Sheep	0	2	1	1	***1	0
Swine	3	2	1	0	0	0
Goat	1	0	1	0	0	0
Fish	1	2	0	0	0	0
Exotic Bird	0	4	0	0	0	0
Exotic Mammal	4	0	0	0	0	0
Wild Mammal	0	0	1	0	0	0
Dog	0	4	0	0	0	0
TOTALS	130	79	17	3	4	17

* subset of fur-bearers
** poisoning
*** helicopter landing

Type of Injury	Fur Bearer	Mink only****	Fowl	Cattle - beef	Cattle - dairy	Horse	Sheep	Swine	Goat	Fish	Exotic Bird	Exotic Mammal	Wild Mammal	Dog	TOTAL
Trauma due to panic	14	11	14	17	4	21	-	3	-	-	-	-	-	-	73
Abortion	7	5	-	3	2	3	-	4	-	-	-	2	-	1	22
Killing/eating young	45	31	-	-	-	-	-	*2	-	1	**1	-	-	-	49
Reduced production***	-	-	32	1	4	1	1	1	-	1	-	-	-	-	41
Death due to trauma	3	2	10	22	4	10	3	3	1	2	3	7	-	3	71
Abandonment of young	3	3	-	-	-	-	-	-	-	-	-	-	-	-	3
Smothering due to crowding	-	-	32	-	-	-	-	-	-	-	-	-	-	-	32
Weight loss	-	-	6	22	-	-	1	-	1	-	-	-	-	-	30
Hatchability	-	-	7	-	-	-	-	-	-	-	4	-	-	-	11
Reduced fertility	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Debris ingestion	-	-	-	1	1	-	-	-	1	-	-	-	-	-	3
Disappearance	-	-	-	1	-	1	-	-	-	-	-	-	1	-	3
Animal quality	-	-	-	3	-	1	-	1	-	-	-	-	-	-	5
Pelt quality	3	3	-	-	-	-	-	-	-	-	-	-	-	-	3
Poisoning	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
Unknown	2	2	1	5	-	1	-	1	-	-	-	-	-	-	10

* crushed piglets
** broke eggs during panic
*** eggs, beef, milk, wool, piglets, foals, fish
**** subset of fur bearers

Table 4. Type of injury cited in the claims files. Numbers of claims for each type of injury are listed by animal grouping

Table 5. Summary of the literature on production-related effects of noise on poultry. In the section under sound exposures, the weighting functions for sound measurements are listed explicitly when known.

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES: Number & Type of Exposures	SOUND EXPOSURES: Duration	SOUND EXPOSURES: Mean Value (dB)	SOUND EXPOSURES: Range of Sound Level (dB)	Comments	Ref
Effect on % laying and mortality	chickens (laying hens)	None	"large flock"	Laying % / % Dead (55dB) 60.2±2 / 0.4 (75dB) 65.1±2 / 0.3 (87dB) 48.2±2 / 0.6 (92dB) 40.1±2 / 0.8	Noise in commercial poultry house from machinery and chickens.	continuous	(A-weighted) 55 75 87 92	Unknown	Noise levels fluctuated throughout the day 10-12 dB higher in morning than at midday.	Belanovskii and Omel'yanenko 1982
Piling and crowding	chickens (broilers) turkeys pheasants (various breeds)	None; No controls	un-known; 210,000 in 10 flocks	No obvious increase in mortalities; no dangerous piling and crowding.	91-210 sonic booms per farm	11 days	Unknown	Unknown	Not a controlled study. Observers untrained and detailed observations not made on any farm. All fowl apparently habituated by previous exposure to sonic booms.	Casady and Lehman 1966
Reduced hatchability	chickens (laying hens - breed not specified)	None	4 groups of un-specified number	No effect observed	6 per day simulated sonic booms	21 days	Pressure levels: 134,148,158,168 (weighting unknown) for 4 groups, respectively	Not specified	Two years of experiments; number of eggs not specified; no statistical analysis and data not presented.	Cottereau 1972

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Piling and crowding; weight loss	chickens (broilers)	None; No control	2 groups (2912, 2856 hens)	Reactions greatest at 1-8 days; reaction declines but never ceases altogether; no mortalities or hysteria. Weight not unusually low.	Mobile sonic boom generator; total of 117 bangs	8-9 weeks	134	Not specified	No control group and no detail or statistical test in reporting. Results difficult to evaluate.	Cottereau 1972
Piling and crowding; decrease in laying rate	chickens (laying hens)	None	1300	Hens startled initially, they habituated after 15 days. No hysteria observed; normal laying curves by comparison with previous years at the same farm.	6 per stimulation, 32 stimulations, 92 total sonic booms.	4 months	134, 300 ms long	Not specified	No data presented and no statistical tests.	
Decreased egg production	chickens (laying hens)				Army maneuvers - air reconnaissance and ground maneuvers	Unknown	Unknown		Commercial poultry farm in South. Abstract only	Hamm 1967
Effect on hatchability	chickens (White Leghorn hatching eggs)	Analysis of Variance	3415 exposed 1890 controls	P>.05 hatch 85.78% exposed 83.6% control	~30/day sonic booms from F-104 and B-58 (600 booms)	21 days	128-135	122-142	Control C7 compromised by handling; abnormally low hatchability.	Heinemn & LeBrocq 1965
Decreased egg production	chickens	None		Noise Type / N (# wks) / x laying Control / % Treatment Bell / 44 / 52.3 / 47.2 1 Siren / 44 / 52.6 / 53.4 2 Sirens / 35 / 53.6 / 51.8	Electric bell Firebrigade siren Two firebrigade sirens	Continuous over 44 and 35 wk study periods	76 110 128		Ivos et al. 1976	

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Reduced laying rate of hens at high noise amplitude	chickens (Hybro & Arber-Acres laying hens)	None speci-fied	Not specified	P value not specified; they report reduced laying rate in hens exposed to highest levels (90 & 128 dB)	Noise from equipment and hens	continuous	84-128		Minimum noise level 84 dB from equipment and hen noise in all groups. Measured laying rates throughout 44-week laying period. Trends not very clear in the graphs of laying rate by week. We don't believe the trend was significant.	Ivŏs and Krsnik 1979
Control of excessive broodiness	turkey (hens)	Dun-can's Multiple Range Test	228 total 18 sound treatment 10 sound control	No change in egg production after treatment. $\bar{X}$ non-laying days: treat. / control days on nest: 5.72 / 29.0 days not on nest: .44 / 4.30 total days: 6.17 / 33.30	1 - jet plane noise	4 min	-	110-135	No change in egg production before and after treatment.	Jeannoutot & Adams 1961
Effects of noise on egg production	chickens (White leghorn hens)	Not speci-fied	100	No effect on laying rate	8 hrs/day continuous	17 days of noise during 8 hr day	92-95 (C-weighted)	82-118	$L_{24\,hr}$ not specified - not clear how they measured their sound levels. Hens startled initially, but production did not decline markedly.	Kagan and Ellis 1974

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Abandonment of eggs or young	turkeys (Eastern wild turkeys, <u>Meleagris gallopavo</u>)	None	4 nests, 20 broods	2 of 4 nests lost to predators. Hens did not leave nests or abandon young.	0-5 real and 4-8 simulated sonic booms	10-15 days during incubation period	-	125-129 simulated booms 127-134 real booms	Sample size small and no controls were used.	Lynch and Speake
Change in pattern of egg laying (away from diurnal/ nocturnal pattern)	chicken (hens)	None	142	No. of eggs laid outside normal lighted period* Treatment: 455 of 1, 141; Control: 2 of 1, 402 * 0600 to 2000	1	57 days Continuous light <u>and</u> radio noise		-	No effect on eggs per cycle. After 57 days noise was discontinued but continuous light remained - no change in established pattern of lay (eggs laid at any hour). Hence, light caused the change in laying pattern.	Morris 1961
Increase in x interval between successive eggs within cycles	chicken (hens)	None	31	24 showed an increase in x interval from 1 to 6 hrs (overall x - 1½ to 2 hrs); 2 showed a decrease in x interval; 5 showed no change	-	-	-	-	Radio noise had no obvious effect - sound level was not measured.	Morris 1961

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES: Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Laying rate decreased more rapidly than controls in pullets treated w/ sound throughout their laying period	chickens (White leghorn and New Hampshire laying hens)	-	(Pooled) Control: Noise:	N / % laying (x±s): 1st mo. / 2nd mo. 34 / 71.8±14.5 / 75.2±18.3 33 / 76.0±11.8 / 73.0±16.9	Jetplane noise-various treatment regimes	1-sound presented throughout experiment-al period 2-sound started at 16 wks and continued 3-sound supplied until one month of age, after pullets began laying, then dis-continued	-	-	Article in Japanese - other details unknown. The authors pooled all treatment groups. They did not show whether breed might have explained all the changes in laying rate. Difficult to interpret English portions of this document.	Okamoto et al. 1963
Decrease in total weight of eggs laid for pullets treated only during 2nd month	•	Analysis of Var-iance	(Pooled) Control: Noise:	Total egg weight (g) N / 1st mo. / 2nd mo. / 2nd/1st(1%) 15 / 1252±176 / 1299±174 / 105.7±21.4 18 / 1092±225 / 1040±308 / 93.4±31.5 Source of variation / df / F / P Treatment x breed / 1 / 5.38 / (<0.05)						•

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Decreased broodiness	chicken	•		N / No. remaining broody Control 6 / 6 / 100% Noise 12 / 1 / 8%		Sound on for 5 min out of every 20 min from 0800 to 2000. Every 3rd night, sound on for 5 min. @ 30 min all night.	115 dB		The one exposed hen that remained broody hatched only 1 chick from 12 fertile eggs.	Stadelman 1958
Death due to smothering	chickens	•	2400	•	1 - jet and propellor aircraft overflight noise 1 expt. that lasted 10 days then equipment broke down for 3 days. Then treatment resumed until chicks 10 wks old	31 days old: 4 hours continuous 45 days old: sound supplied for 5 min. out of every 20 min. from 0800 to 2000. Every 3rd night, sound supplied for 5 min. out of every 30 min. throughout the night.	•	100-118	One chicken smothered to death - 31 day old broilers reacted violently, at 45 days saw crowding but no mortality. Birds habituated after 3 days of intermittent sound but some rected again after a 3 day lag in exposure. No effect seen on mean body weight, meat yield or quality.	Stadelman 1958

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Crowding (death due to smothering)	chickens (young broilers)	2400 31 day old broilers		31 days old - 1 died	1	4 hrs	120 dB re: 0.0002 microbars	-	No effect on hatchability, growth rate, body weight, feed efficiency, or meat quality Spermatogenesis	Stadelman and Kosin 1957
				45 days old crowding but no deaths	continuous	Intermit-tent from 45 days to 70 days of age (one 3 day lapse)	120 dB re: 0.0002 microbars	-		
Decreased egg quality (blood spots)	chickens (hens)	?	125 each group	P<.05	1/hr during the day for 10 days.	1 min	dog whistle (high frequency)		No change in albumen height, egg weight, Haugh score, or shell thickness. Difficult to interpret without sound levels.Stiles and Dawson 1961	
				P<.01	1	continuous for 10 days	"medium loud" radio			
				P<.05	1/hr during the day for 10 days.	1 min	low frequency whistle			
Piling up	chickens (1 wk old)	None	303	Some piling observed in chicks 1-7 days old; no detectable excess losses.	12 F4f jets per day between 1030 & 1100	3 days	125		Piling up was not observed in older chicks; was not observed during simple overflights of BO 105.	Von Rhein 1983
					1-3 BO 105 hoverings per day	6 days	105			

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES				Comments	Ref
					Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)		
Egg consumption	chickens (laying hens)	?	140	One hen lost, apparently to a foot injury; not directly following overflight. Some eggs eaten after water shortage on day of experiments.	1-3 BO 105 hoverings per day (6 total)	3 days	105	-	Water accidentally turned off for parts of two days; egg consumption probably the result of water deprivation. No egg consumption was observed during similar noise exposure earlier that month.	*
					5 BO105 overflights per day	3 days	-	-		

Table 6. Breeds of cattle and horses with excitable or highly reactive temperaments. These breeds are most likely to respond strongly to aircraft overflights.

BREED	TEMPERAMENT	REFERENCE
Dairy cattle		
Ayrshire	Slightly high strung	Coletti 1963
Jersey	Slightly nervous	"
Milking Shorthorn	Easily aroused if not handled properly	"
Beef cattle		
Aberdeen-Angus	Nervous and excitable	Vaughan 1948
Brahma or Zebu	Very active, often vicious and difficult to handle, jump high fences easily	"
Highland	Nervous and excitable	"
Horses		
Arabian	Docile and well-mannered but highly spirited	"
Hackney horse	Spirited, bold	"
Hackney pony	Vigorous, requires handling by experienced horsemen	"
Thoroughbred	Active and energetic, highly nervous, some are hot-tempered and erratic	"

Table 7. Summary of literature on production-related effects of noise on cattle, including dairy cattle and veal calves. Numbers in parentheses under "Number and Type of Exposures" designate hoverings; those under "Mean Value" and "Range" designate sound levels reached while hovering.

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES: Number & Type of exposures	SOUND EXPOSURES: Duration	SOUND EXPOSURES: Mean Value (dB)	SOUND EXPOSURES: Range of Sound Level (dB)	Comments	Ref
Breaking through or jumping	cattle (pregnant Holstein-Freisian cows)	None	10	All the cows ran after initial exposure. One never habituated. Two cows jumped over a fence after exposure to hovering helicopter. Cows avoided aircraft after first several exposures.	9(1) Alouette II 12(1) BO 105 13 Alpha jet 15 A-10 7 Starfighter F104g 11 Phantom F4f 9(3) Bell UH 1D	30 min.	(A-weighted) 102(110) ± 1.6 102(110) ± 1.8 107 ± 1.8 105 ± 6.4 103 ± 6.0 118 ± 3.5 106(111) ± 1.6	(A-weighted) 100-104 100-105 104-110 94-116 90-107 110-124 104-109	Some sensitization to Alouette helicopters, BO-105; eventual habituation. No injuries occurred as result of 2 cows' escape, but author attributes this to good footing and fencing (e.g., not barbed wire) in experimental paddock. No interruptions of gestation (e.g., stillbirths) were observed.	Beyer 1983

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES				Comments	Ref
					Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)		
Altered food intake, trauma due to panic	cattle Angus cows and calves, Hereford and Angus steers	least squares ANOVA; Duncan's multiple range test Post Hoc	38	All animals startled, return to normal 1 min. No panics. Habituated substantially by second boom. No effect of booms on feed intake apparently, although there were differences for some trials. No panics or injuries. Steers reacted least.	2 sonic booms	15 min. interval between	140 dB (max SPL, unweighted)	Not specified	Kicking, biting and running not on their list of behaviors. We presume they recorded them because they mention them later. Reporting of statistics difficult to interpret. Activity ratings not very useful, so percentages of responses not measured adequately.	Bond et al. 1974
Trauma due to panic	dairy cattle beef cattle	None	320 10,000	No mortalities or injuries observed. N exposures / % abnormal dairy cattle: 87 / .01 beef cattle (farm 1): 65 / .15 beef cattle (farm 10): 103 / 0	aircraft unspecified. See results column.	booms heard over 11 days	Unknown	Unknown	Cattle well-habituated to overflights. Author explains difference between two groups of steers by observer differences. "Abnormal" behavior defined as running, bellowing, or moving around at unusually high rates.	Casady & Lehman

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES: Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Changes in milk ejection	cattle (Jersey cows)		3	milk ejection ceased briefly (always <1 hr)	exploding paper bags	every 2 min.	Not measured	Not measured	milk ejection ceased for < 1 hr; cows habituated to the surprising noise.	Ely & Peterson 1941
Trauma due to panic	cattle (Swedish red & white breed): 2 dairy cows 10 heifers 8 steers	None	20 cattle 420 obs.	In 2 of 403 responses animals butted one another (.5%). No damage, stampedes, or panics. Runs at most 20 meters. Tendency to startle strongest to rise times <.1 ms and >6 ms. Threshold of response to subsonic flights at ˜100dB. Habituation rapid.	9-10 times per day - J35 Draken fighter aircraft overflights (low-level subsonic and supersonic). Total exposure: 28 sonic booms (2000-6500 m jet altitude) 10 subsonic overflights (50-200 m jet altitude)	4 days	(A-weighted) 97 supersonic increasing from 95-129 subsonic	(A-weighted) 95-103 supersonic 95-129 subsonic	Animals had probably been exposed to sonic booms and low-level overflights before; exposure level unknown but likely only occasional and much less intense than experimental exposure. Adaptation observed after 3 days of exposures. The author did not show relation between rise time and amplitude.	Espmark et al. 1974

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Abortion, trauma due to panic	cattle Holstein-Friesian	None	20	no controls; 10 calves aborted or premature, 5 due to disease. Author felt that some abortions and premature births may have been due to overflights, but disease rates high. One cow pushed head and foot through fence; not injured.	39(5) BO 105 45(9) Alouette II 36 Phantom F4f	4 days, 30 min/day 3 days, 30 min/day 3 days, 30 min/day	(max A-weighted) SPL 102(115) ± 1.0 99(105) ± 2.5 118 ± 1.6	(max A-weighted) SPL 101-108 95-103 115-120	Since there were no controls, difficult to say whether the losses were due to overflights or management problems. Losses occurred 1-78 days after last overflight.	Heicks 1985
Abortions or premature births	cattle (pregnant cows)	None	10	no controls; apparent increase in numbers of stillbirths.	7 Alouette II 10 BO 105 12 Phantom F4f 10 Bell UH 1d 14 Fiat G91 6 Starfighter F104g	16 min/day 38 min/day 20 min/day 28 min/day 22 min/day 10 min/day	95(102) ± 2.5 92(108) ± 1.42 120 ± 1.8 90(101) ± 4.5 96 ± 2.11 115 ± 3.7	91-96 90-94 115-122 78-94 92-101 108-118	One premature birth and 2 abortions attributed to overflights; abnormally high disease rates observed in herd so conclusion suspect.	Heuweiser 1982
Decline in milk production	dairy cattle	Unknown	Unk.	Some decrease observed at high continuous noise levels: Noise level — Effect 80 dB — No effect 90 dB — Reduced milk yield 105 dB — Further reduced milk yield See appended table at end of Table 6 for milk yield.	Continuous noise from farm machinery	-	-	-	See results column; method of sound measurement not specified	Kovalcik and Sottnik 1971
Decreased milk production	cattle		5		speed boat races	72 hrs/mo for several months	-	-		Oda 1960 (cited in Bond 1971)

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES: Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Decreased milk production	dairy cattle	ANOVA	8*	* herds 1,2,3 miles from AFB. Herds compared to one another P>.05 bases 1-7; P<.08 8th base		frequent	Not measured	Not measured	Milk production in farms different distances from an Air Fore base were compared. Marginally significant results found at 1 of 8 bases; authors suggest reason for difference at 8th base was that average herd size was very different among zones around this base.	Parker & Bayley 1961

Appendix to Kovalcik and Sottnik 1971:

Milk yield in kg/animal-day:

Noise level	Trial 1 15	Trial 2 15	Trial 3 15
80 dB	17.3-17.7 (17.4)	-	-
90 dB	15.4-16.2 (15.8)	17.4-18.0 (17.8)	-
105 dB	14.1-15.0 (14.5)	16.7-17.3 (16.9)	15.8-16.6 (16.3)

Table 8. Summary of claims for damage to cattle that report traumatic injuries or deaths or escapes (claims 1957-1988).

				Number Dead/Lost			Number Injured			All Losses		
	Number of herds	Total number	Number per herd	Number dead or lost	% of herd lost	Number lost per herd	Number dead or lost	% of herd lost	Number lost per herd	Number dead or lost	% of herd lost	Number lost per herd
Herds with sizes known:												
All	23	674	203.5	57	1.2%	2.5	47	1.8%	2.1	104	2.2%	4.6
Dairy	2	106	63	2	1.9%	1.0	5	4.7%	2.5	7	6.6%	3.5
Veal	2	371	185.5	2	.5%	1.0	0	0	0	2	.5%	1.0
Other cattle	19	197	222.2	53	1.3%	2.8	42	1.0%	2.4	96	2.3%	5.2
All herds:												
All	37	-	-	74	-	2	83	-	2.3	157	-	4.3
Dairy	5	-	-	5	-	1.0	7	-	1.4	12	-	2.4
Veal	5	-	-	5	-	1.0	0	-	0	5	-	1.0
Other cattle	27	-	-	64	-	2.4	76	-	2.9	140	-	5.3

Table 9. Rates of abortion in horses and cattle exposed to aircraft noise in a series of experiments by the Veterinary College of Hannover.

Study	Number of flights > 90 dB	Number of cows	Calves lost to infection	Calves premature	Calves aborted for unknown reasons	Calves normal
Heicks 1985	117	20	5 (25%)	4 (20%)	1 (5%)	9 (45%)
Heuweiser 1982	59	10	2 (20%)	1 (10%)	1 (10%)	6 (60%)
Beyer 1983	81	10	0	0	0	10 (100%)
TOTALS	**257**	**40**	**7 (17.5%)**	**6 (15%)**	**2 (5%)**	**25 (62%)**

Study	Number of flights > 90 dB	Number of mares	Foals lost to infection	Foals premature	Foals aborted for unknown reasons	Foals normal
Erath 1983	96	11	1 (9%)	1 (9%)	0	9 (82%)
Kruger 1982	66	10	0	0	0	10 (100%)
TOTALS	**162**	**21**	**1 (4.8%)**	**1 (4.8%)**	**0**	**19 (90%)**

Table 10. Summary of literature on production-related effects of noise on horses. Numbers in parentheses under "Mean Value" designate sound levels reached while hovering.

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES: Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Altered food intake, trauma due to panic	horses (Shetland pony geldings)	least squares ANOVA; Duncan's multiple range test POST HOC	8	All animals startled, return to normal 1 min. No panics. Habituated substantially by second boom. No effect of booms on feed intake overall, although there were differences for some trials. No panics or injuries. Ponies react most, steers least.	2 sonic booms	15 min interval between	148	Not specified	Kicking, biting and running not on their list of behaviors. We presume they recorded them because they mention them later. Reporting of statistics difficult to interpret. Activity ratings not very useful, so percentages of animals running not measured adequately.	Bond et al. 1974
Trauma due to panic	horses (breed not specified)	None, No controls	100	4.5% of horses altered their behavior in response to sonic booms. Virtually all changes in 1st 4 days of 11 days of experiment.	87 sonic booms	11 days	Unknown	Unknown	Purely observational study of habituated horses. 4-8 booms/day in area. Observations made by untrained volunteers. Possible habituation to study procedures throughout.	Casady and Lehman 1966

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Increased aggression (biting, kicking) or attempts to flee	horses (pregnant mares of various breeds)	None; No controls	11	No injuries observed; No escapes	36 F4F 25 BO 105 5 BO 105 hovering & swinging	28 min/day 23-40 min/day 4-14 min/day	117 ± 2.7 106 ± 3.2 102 ± 6.5	105-122 96-112 996-110	No injuries or escapes were observed, but authors note that they might have occurred if paddocks had poor footing or hard-to-see fences. Some habituation was observed.	Erath 1983
Abortions	*	*	*	No excess abortions						
Trauma due to panic	horses (Thorough-bred horses and ponies of various ages)	None; No controls	11 Thoroughbreds, 8 ponies	All startled. No panics observed on initial exposure, even in horses confined to loose box. Animals oriented and approached simulator. Sonic booms were not aversive in a conditioning experiment.	Simulated sonic booms (number not specified). Exposures given in short series.	Not specified	130 dB (Weighting not specified)	100-125 N/m²	Animals apparently naive at start of experiments. No differences in responses of ponies and thoroughbreds. Some sensitization if one boom followed another within 2 min.	Ewbank an[illegible] Cullinan 19[illegible]

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Intensive aggression or attempts to flee	horses (pregnant mares of various breeds)	None; No controls	10	No injuries observed No escapes	8 Fiat G91	12 min/day	107±2.6	105-109	No injuries or escapes. Authors suggest accidents/trauma could occur under different test conditions (e.g., if mares were not allowed to flee). Habituation was observed to BO 105, F104g, and Bell UH1d but mares seemed to become sensitized to the Alouette II.	Krüger 1982
					10 Alouette II	20 min/day	99(105)±2.5	95-103		
					11 Phantom F4F	22 min/day	118±1.6	115-120		
					11 Starfighter F104g	18 min/day	105±1.9	101-108		
Abortions				No excess abortions	13 BO 105	27 min/day	102(115)±1.0	100-103		
					12 Bell UH 1d	23 min/day	108(108)±3.2	106-111		
					(In order of increasing stressfulness according to author)		(A-weighted sound levels)			

Table 11. Summary of literature on production-related effects of noise on sheep and goats.

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES: Number & Type of Exposures	SOUND EXPOSURES: Duration	SOUND EXPOSURES: Mean Value (dB)	SOUND EXPOSURES: Range of Sound Level (dB)	Comments	Ref
Increased weight gain	sheep (lambs)	ANOVA, Duncan's multiple range test	15 control 15 noise (60 total for all conditions)	(<.05)	see Ames 1974	75 USASI noise IMS noise		-	Also saw significant (<0.05) differences between acclimated and non-acclimated groups	Ames 1978
Digestive responses - ↓ dry matter intake, - ↑ urinary creatinine	sheep	least squares ANOVA Duncan's LSD	4 (same animals used as their own controls)	(<0.05)	USASI continuous noise IMS - noise plus intermittent quiet (11 hrs noise, 13 hrs quiet per 24 hr period)		(ref $2x10^{-4}$ dynes/cm^2) 75 USASI, 100 USASI, 75 IMS, 100 IMS	-	Saw no change in rumen motility, nitrogen metabolism, water excretion or retention. Did not test body weight	Harbors et al. 1975
- ↑ digestibility coefficient				(<.003-.0006)	3 sound exposures music IMS USASI		75 IMS 100 IMS	-		
- ↑ metabolizable energy				(<0.05)			75 IMS, 100 IMS	-		

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Increased gain and feed efficiency	sheep (lambs)	least squares ANOVA, Duncan's multiple range test	60	(<0.05)	21 day control, 12 day exposure	USASI - continuous IMS - noise plus intermittent quiet (11 hrs noise, 13 hrs quiet during 24 hrs)	75 USASI noise IMS noise	-	See Archart & Ames 1972 for amount of increased daily gain	Ames 1974 (in 2209)
Increased number of corpora lutentia	sheep (ewes)	?; author states that noise significantly increased number of corpora lutentia	79	# corp. lut.: Control: 1.11 Noise: 1.75	days 14-17 of estrous cycle	intermittent	400 Hz pure tone, 100 dB	-		
Increased number of lambs born	sheep (ewes)	?; author states there were significant increases in number of lambs born		Control: 98.2% Noise: 114%	days 14-17 of estrous cycle	-	4000 Hz tone	-		

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES: Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Decreased milk yield	goats	-	5	Animal / ↓in yield per day / When ↓ occurred (noise load) 1 / 3-11% / 1st-6th 2,4 / 0.6-55% / 1st-3rd 3 / 0.6-55% / 1st-4th 5 / no change / -	Noise of different types given every other hour for 48 hours (=1 exposure). Animals given several over course of study. Types of noise: 1) 3kHz "simple sound", intensity range 70-98 phons 2) "complicated sound" (highway noise, wireless talk, jet noise, intensity 65-90 phons)				No further decrease after periods shown (=habituation?). Evidence for habituation after 2-5 days of exposure. Saw no change in total dry matter or crude protein of milk; saw transient increase in concentration of butter fat for two goats.	Sugawara and Kuzashi 1979
Increased activity (running as a group)	sheep		18		9-10 times per day Total exposure: 28 sonic booms (2000-6500 m jet altitude; 95-103 dBA); 10 subsonic overflights (50-200 m jet altitude)	4d	J35 Draken fighter aircraft overflights (low-altitude subsonic		Animals had been exposed to sonic booms and low level overflights before - exposure level unknown but likely only occassional and much less intense than other experimental exposures. Some adaptation observed.	Espmark et al. 1974

Table 12. Changes in milk yield before, during, and after experimental exposures to noise (data from Sugawara and Kuzashi 1979). The values were obtained by counting the number of times yield during experimental period exceeded values during pre- or post-experimental periods.

Productivity	Experimental vs. Pre-experimental	Experimental vs. Post-experimental
Increased	12	15
Decreased	16	14
Equal	4	4

Table 13. Summary of literature on production-related effects of noise on swine. Numbers in parentheses under "Number & Type of Exposures" designate hoverings; those under "Mean Value" and "Range" designate sound levels reached while hovering.

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES: Number & Type of exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Changes in suckling behavior	swine	None	Control: 3 sows 40 piglets Noise: 3 sows 38 piglets	Control: sow initiated 68%, terminated 52% of sucklings Noise: sow initiated 6%, terminated 19% of sucklings	fan noise	"from day two to day four after farrowing"	85 dBA	-	Authors suggest piglets were getting less milk from sow (were hungrier, and therefore initiated more suckling). Authors never weighed piglets, so speculation not proven.	Algers 1984
Increase in mortality rate	swine	None	unknown	"Mortality rate in swine caused by noise stress was higher in swine with higher weight gain and vice versa: lower in swine having smaller weight gain." (p.165)	continuous noise	-	-	112-121 dB	Article in Polish.	Ivős & Krsnik 1979

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES: Number & Type of Exposures	SOUND EXPOSURES: Duration	SOUND EXPOSURES: Mean Value (dB)	SOUND EXPOSURES: Range of Sound Level (dB)	Comments	Ref
Increased number of abortions or stilllbirths	swine (pregnant meat sows)	No controls; No statistical analysis; graphical analysis	22	No accidents or panics, no aggression. One sow lost in transport, one litter aborted after a fight with a boar. One abortion due to unknown causes during experiments. Young born alive/litter: N=18, sd=3.47, X=8.5 Young per litter: N=19, X=9.58, sd=2.97	36(3) BO 105 36(3) Alouette II 36 Phantom F4F	34-37 min/day, 3 days 37-41 min/day, 3 days 27-28 min/day, 3 days	102(115)±1.0 99(105)±2.5 118±1.6	101-108 95-103 115-120	The sow that aborted unexpectedly lost her catheter so not clear that the aircraft overflights caused the abortions. Hormone profile incomplete. All sows were transported from the experimental site on 5/21; one sow died during transport. No obvious relation between hormone levels and overflights.	Schriever 1985
Killing or crushing piglets	swine (commercial meat sows and piglets)	ANOVA	17 sows 17 lit-ters	No piglets crushed or eaten; sows carried piglets once, piglets crowded together 5 times. No difference between growth of control and experimental piglets.	37 sequences of 213 sounds. Sounds were constant tones, alternating tones, and freqeuncy sweeps.	Variable exposures 1-34 minutes long, 5-16 exposures per day.	varied with sequence (A-weighted)	100-120 dB	Tones, warbles and sweeps tested prior to arrival of sound simulation system.	Winchester et al. 1959

Table 14. Percentage of each type of response exhibited by sows and piglets exposed to high-amplitude tone bursts (from Winchester et al. 1955). Responses were scored by looking at the behavior that followed the first presentation of the sound (when the sows were presumably naive).

Response Type	Number of Responses	Percent of Total
Sow startles or starts up	15	40.5%
No response	9	27%
Sow searches pen	6	16%
Piglets crowd	5	13.5%
Sow carries piglets	1	2.7%
Sow shakes head	1	2.7%

Table 15. Summary of literature on production-related effects of noise on fur-bearers. Numbers in parentheses under "Mean Value" and "Range" designate sound levels reached while hovering.

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES: Number & Type of Exposures	SOUND EXPOSURES: Duration	SOUND EXPOSURES: Mean Value (dB)	SOUND EXPOSURES: Range of Sound Level (dB)	Comments	Ref
Increased number of infertile females	mink (females)	X^2	48 experimental 48 control	No statistical difference in success between control and experimental groups. Slight difference in whelping date.	3 series of Aircraft overflights and hoverings with and without visual cues. Simulated overflights.	30 min.	120 (F4f) 95(98) (BO 105)	(A-weighted) 118-127 91-104(100)	Author suggests t number of stillbirths may be an artifact of the way nest boxes were checked.	Brach 1983
Increased number of stillbirths or deaths at birth	"	Not tested		Slightly better success in experimental group.						
Shorter gestation period by 3½ days	"	Unknown		Peak number of litters for control group produced 30 April - 5 May; peak number of litters for experimental group produced 28-30 April. No apparent effect of this difference on success; more births in exposed animals.	"	"	"	"	Author states gestation periods were signifiantly different but does not specify test. Author explains the difference by a difference in management of the two groups.	"

Effect Tested	Animal	Test Used	Tot N	Result	SOUND EXPOSURES: Number & Type of Exposures	Duration	Mean Value (dB)	Range of Sound Level (dB)	Comments	Ref
Increased number of still births or deaths at birth	mink	ANOVA	257*	EXPT'L / CONTROL LITTER SIZE 4.5 kits / 4.4 kits KIT MORTALITY 7.2% / 8.6%	8 per day simulated sonic booms	10 days	138	Not given	Mink were tested prior to whelping. * 163 females tested in 3 exp. groups + one control group of 94 females.	Travis et al. 1968
Mothers consuming kits after disturbance Reduced kit weight gain	mink recessive for Aleutian gene (stress-prone)	Analysis of Variance	520*	No significant differences between control and experimental groups in numbers of kits, kit weight at pelting, or pelt value. No kits killed by dams. No panics. See text for details of results.	3 real boom from F4E aircraft at 2440 m, 1 dynamite blast, 3 simulated booms - rise times .4 ms	1 hour	142 for sonic booms 138 for simulated booms	-	Experiments conducted at peak of whelping season (40% of mothers newly-whelped). There was a strong effect of age of mother on success in the sumulator group, for reasons unknown.	Travis et al. 1972

Table 16. Numbers of behavioral responses to disturbance per 10 mink per hour of observation. Data from Travis et al. 1972.

Observation types	Number of females	Number of booms per hour	Number that startle or peer	Number that enter the nest	Number that carry kits	Number that screech
Baseline 7 May	40	0	6	11.17	0	0
Baseline 8 May	40	0	6.25	12.83	0	0
Baseline 9 May	40	0	12	16.67	0	0
Baseline 10 May	40	0	5.667	10.58	0	0
Sonic Booms 11 May	40	3	23.16	19.0	.58	0
Simulated sonic booms 12 May	20	3	25.83	22.17	0	.16
Dynamite Blast 11 May	40	1	10.3	5.33	.16	0
Baseline after booms 13 May	12	0	5.55	12.78	0	0

Table 17. Measures of success in mink exposed to simulated and real sonic booms (data from Travis et al. 1972).

MEASURE	RESULT			SIGNIFICANCE
	Control	Real Boom	Simulated	
% females whelping	79.8%	82.5%	78.1%	Not Tested
Whelping date (Julian days)	131.5 days	131.6 days	132.6 days*	P<.01
Length of gestation	45.7	45.9	46.8	NS
Number of kits/ female whelping	4.59	4.78	4.20	-
Number alive/whelping	4.11	4.21	3.74*	* 2 year old females had significantly smaller (P<.05) litters in simulator group. Significance could not be evaluated due to interaction effect.
Number kits 5 days	3.27	3.19	3.15	
Number kits 10 days	3.15	3.08	3.06	NS
Kit count pre boom	172	172	96	-
Kit count post boom	192	185	96	-
Kit counts at 49 days	2.80	2.78	2.80	NS
Mean weight at 49 days	357 g	344 g	346 g	NS
Mean weight at 3 mo.	912 g	912 g	885 g	NS
Mean weight at pelting	1642 g	1610 g	1592 g	NS
Pelt value	$10.74	$10.76	$10.52	NS

* Significantly different success

Table 18. Responses of large stock to aircraft overflights and sonic booms. The column marked "accidents" indicates the animals that collided with fences or other barricades during aircraft overflights.Table 18.

	Aircraft Type	SPL (dB)	Running, biting or kicking after first exposure	N	Number escapes	Previous experience	Number with dangerous accidents	State of Confinement
Erath 1983	J	120	100%	11	0	N	0	Confined
Krüger 1982	H	106	100%	10	0	N	0	Free-ranging
Heicks 1985	H	100	100%	20	0	N	1	Confined
Beyer 1983	H	107	100%	10	2	N	0	Free-ranging
Heuweiser 1982	H	102	100%	10	0	N	0	Free-ranging
Espmark et al. 1974								
sheep	S	103	5%	18	0	H	0	Free-ranging
	J	109						
cattle	S	103	50%	20		H		Free-ranging
	J	109						
Bond, J. 1974	S							
ponies		140	(Most)	6	0	H	0	Free-ranging
cows		140	(Mid)	8	0	H	0	Free-ranging
steers		140	(Least)	24	0	H	0	Free-ranging
Casady & Lehman 1967	S							
beef		-	<1%	2980	0	H	0	
dairy		-	<1%	6032	0	H	0	
sheep		-	0	2750	0	H	0	
horses		-	<1%	1193	0	H	0	
Ewbank et al. 1974	S	130	0%	11	0	?	0	Free/Confined
	S	130	0%	8	0	?	0	Free/Confined

Table 19. Mortality rates in poultry exposed to low-altitude aircraft overflights. The column marked "sequence" indicates the number of each exposure in a sequence of overflights.

a.

Sequence	Number of poults or pullets	Density (per m^2)	Age (days)	Number lost	Percent lost/day
1	140*1	7	210	1	.001785
3	140	7	224	0	0
6	140	7	238	0	0
9	140	7	245	0	0
1	303	113	4	3	.00110
3	303	113	8	0	0
6	303	113	22	3	.00090
9	303	113	36	1	.0003
1	327	12	27	4	.001355
3	327	12	31	6	.00166
6	327	12	45	8	.002246
9	327	12	59	0	0
1	2400*2	-	31	1	.00042
13	2400	-	45	0	0

*1 - Stadelman and Kosin 1955
*2 - Stadelman 1958a

b.

Number lost/ Number of birds	Number Lost	Number of Birds	Source
.0007	1	140	Von Rhein (1983)
.010	3	303	"
.012	4	327	"
.0004	1	2400	Stadelman and Kosin (1959)
.375	13,134	35,000	Claims Files
.468	83,315	177,919	Claims Files

Table 20. Mixed regression model showing the relation between heart-rate and the features of the aircraft overflights in two studies of cattle (Beyer 1983 and Heicks 1985).

N: 358 Squared Multiple R: .298

ANALYSIS OF VARIANCE

Source	Sum-of-Squares	DF	Mean-Square	F-Ratio	P
Regression	2.361	10	0.236	14.701	0.000

VARIABLE	COEFFICIENT	STANDARD ERROR	T	P (2 TAIL)
Constant	0.679	0.289	2.350	0.019
Sequence	-0.013	0.007	-1.765	0.078
Order	-0.018	0.003	-5.266	0.000
Interval	-0.000	0.000	-1.319	0.188
Aircraft Type	-0.130	0.055	-2.376	0.018
Duration	-0.008	0.002	-4.827	0.000
SPL	0.002	0.003	0.779	0.437
Study	-0.026	0.022	-1.167	0.244
Order* Interval	0.000	0.000	1.281	0.201
Aircraft Type* Duration	0.009	0.001	5.879	0.000
Aircraft Type* SPL	0.001	0.001	1.377	0.169

Table 21. Mixed regression model showing the relation between heart-rate and the features of the aircraft overflights in two studies of horses (Erath 1983 and Krüger 1982).

N: 346 Squared Multiple R: .469

ANALYSIS OF VARIANCE

Source	Sum-of-Squares	DF	Mean-Square	F-Ratio	P
Regression	5.087	11	0.462	26.800	0.000
Residual	5.763	334	0.017		

VARIABLE	COEFFICIENT	STANDARD ERROR	T	P (2 TAIL)
Constant	-1.169	0.254	-4.605	0.000
Sequence	-0.008	0.007	-1.136	0.257
Order	-0.018	0.006	-3.187	0.002
Interval	-0.000	0.000	-2.716	0.007
Aircraft Type	0.305	0.069	4.395	0.000
Duration	0.000	0.000	0.902	0.368
SPL	0.008	0.001	5.810	0.000
Study	0.277	0.050	5.498	0.000
Order* Interval	0.000	0.000	2.730	0.007
Aircraft Type* Duration	0.000	0.000	0.192	0.848
Aircraft Type* SPL	-0.002	0.000	-4.029	0.000
Study* Aircraft Type	-0.031	0.012	-2.599	0.010

APPENDIX 5

CITASAN BIBLIOGRAPHY
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